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COVER

A large proportion of the Pooncarie area in south-west NSW is covered with dune mallee dominated by *Eucalyptus socialis* and *Eucalyptus dumosa* with an understorey of *Triodia scariosa* subsp. *scariosa*. Due to its occurrence on low nutrient sandy soils, dune mallee remains in better condition compared to other plant communities such as belah-rosewood and chenopod shrubland which have been more heavily grazed or cleared over the last century. Mallee Dragon in foreground (artwork by Lesley Elkan).

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Allan Cunningham

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The native grasslands of the Riverine Plain, New South Wales

J.S. Benson, E.M. Ashby and M.F. Porteners

Benson, J.S., Ashby, E.M. and Porteners, M.F. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1997. The native grasslands of the Riverine Plain, New South Wales. Cunninghamia *5(1): 1–48.* A botanical survey of the derived, temperate, tussock grasslands of the Riverine Plain, bounded by the towns of Jerilderie, Deniliquin, Hay and Narrandera on the south western Plains of New South Wales, was conducted in spring 1995. Sample sites were selected to cover the different types and extent of grassland in the region. A number were placed at locations known to contain the Plains-wanderer (*Pedionomus torquatus*) – an endangered ground bird. All vascular plants were recorded (including cover estimates for each species) in 67, 10 m × 20 m quadrats. Grassland structure, physiographic attributes and an estimate of condition were also recorded for each quadrat. 224 species were recorded, of these 58 (25%) were exotic. Six plant communities were selected from an analysis of the floristic data using an agglomerative hierarchical cluster analysis. These communities are described in the text. Six nationally listed rare or threatened species were recorded, one of which (*Swainsona murrayana*) is common in the region and requires a review of its status. A number of plants were recorded only once. The collection of *Leptorhynchos scaber* was the first of this species in NSW and it should be considered endangered in NSW. Palatable species such as Kangaroo Grass (*Themeda australis*) and the Native Yam (*Microseris lanceolata*) have been severely depleted by grazing and are now rare in the region. A list of sites of botanical significance based on this and previous studies is provided, using the criteria of rare species presence, representativeness and condition. These sites occur in travelling stock routes, roadsides and privately-owned paddocks, all of which appear to have been less disturbed by grazing or ploughing. The main threats to the native grasslands are the extension of cultivation (including rice), rising soil salinity, pasture improvement, inappropriate grazing and small-scale urban development. A discussion is provided on the management of native grasslands in the region.

Introduction

The lowland grasslands of south-eastern Australia are among the most threatened and poorly conserved ecosystems in the nation (McDougall & Kirkpatrick 1994). A number of recent botanical studies have been undertaken in some of these grasslands (Stuwe 1986–Basalt Plains, Victoria; Benson 1994–Monaro, New South Wales; Sharp 1994–Australian Capital Territory; Kirkpatrick et al. 1988–Tasmania). In contrast to previous botanical research in native grasslands that concentrated on their pasture value (for example Robards et al. 1967), these studies have classified the native grasslands, documented important sites for protection and commented on grassland management for conserving native species.

The definition of a native grassland used in this survey was: *a grassland where >50% of the vegetative ground cover is composed of indigenous species of grasses and forbs (species* *native to the area before European settlement), >50% of the number of species are native, and where the minimum standing vegetation ground cover, alive or dead, exceeds 10%* (Benson 1996). Areas where woody vegetation such as Myall, saltbush or cottonbush exceeded 10% cover were defined as shrublands.

In the Australian-wide classification of Moore (1970), the Riverine Plain grasslands were mapped as 'temperate shortgrass' dominated by *Danthonia-Stipa-Enneapogon*. Later, Moore (1993) reclassified them as 'saltbush-xerophytic mid-grass communities' (*Atriplex-Maireana-Chloris-Stipa*). This recognises that the Riverine Plain grasslands have been derived from a previous vegetation dominated by chenopod shrubs and *Acacia pendula* (Moore 1953a). Benson (1996) defines a derived or secondary native grassland as: *A 'native grassland' remaining after the removal or dieback of previous woody canopy vegetation (shrubs and trees), to a point where woody vegetation has less than 10% cover.*

Our survey of the native grasslands of the NSW section of Riverine Plain aimed to classify the different types of native grasslands present, discuss their floristic composition (including significant plant species) and document sites of botanical significance.

The study area

The study area is confined to that part of the Riverine Plain (Butler 1950) in New South Wales that contains native grasslands. It extends from Ivanhoe in NSW in the north to

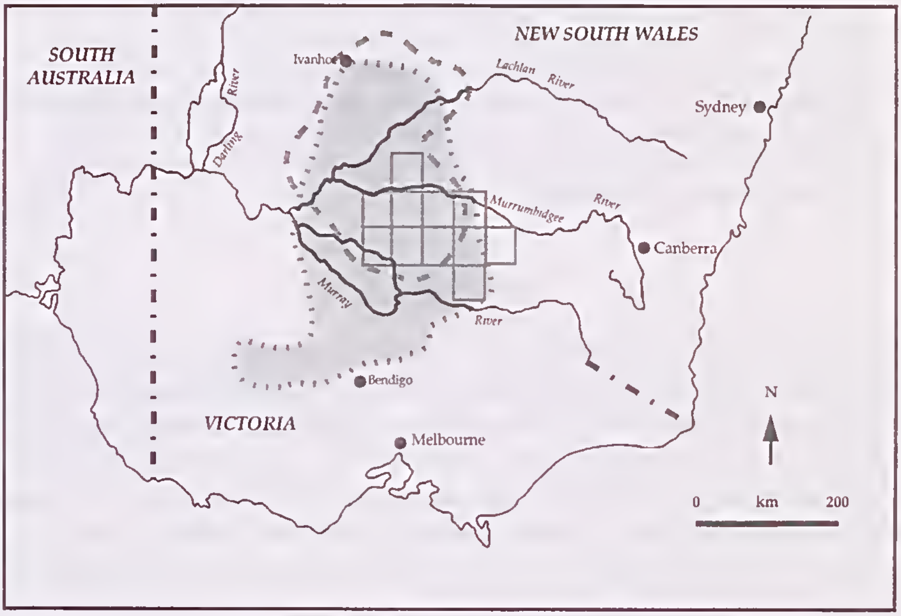

Fig. 1. Location of the Riverine Plain as defined by Butler (1950) (shaded area), the Hay Plain as defined by Porteners (1993) (dashed line) and the 1:100 000 map sheets that cover the region where native grassland occurs (see also Fig. 3).

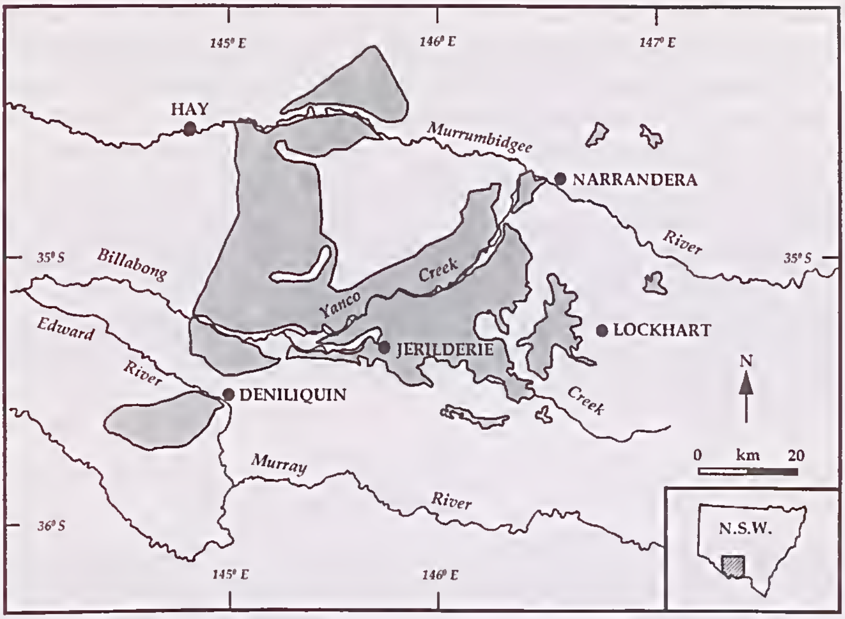

Fig. 2. Extent of derived native grasslands on the NSW section of the Riverine Plain (derived from Beadle 1948 and Moore 1953a). Since the 1920s much of this native grassland has been altered by cultivation and pasture improvement. The area would have originally been vegetated with chenopod shrubland and Myall (*Acacia pendula*) open woodland.

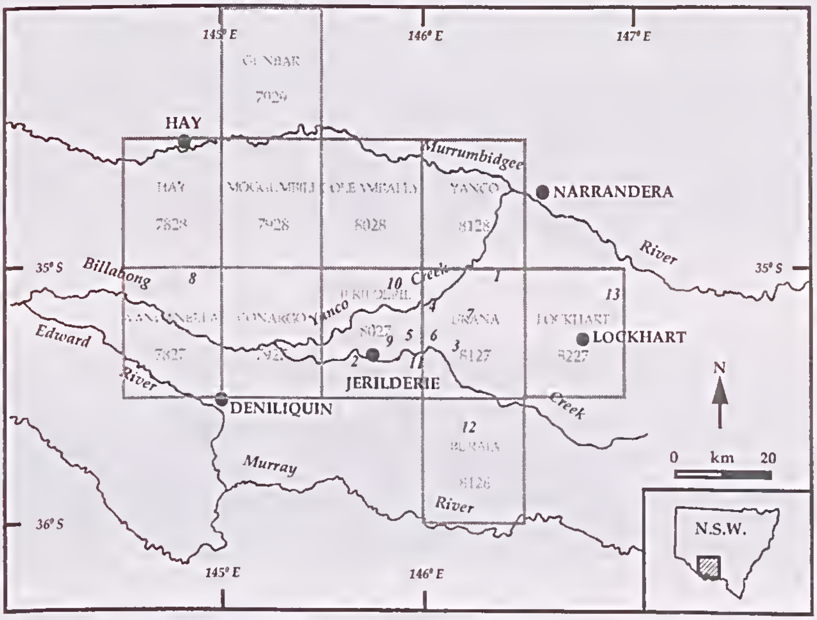

Fig. 3. The native grasslands extend over a region covered by eleven, 1:100 000 map sheets from Lockhart in the east to Hay in the north-west. Numbers 1– 13 indicate the approximate location of areas containing sites of botanical significance.

central-western Victoria in the south (Fig. 1). The Hay Plain, as defined in Porteners (1993), is principally a subset of the Riverine Plain and is mainly dominated by *Atriplex vesicaria* (Bladder Saltbush) and other species in the Chenopodiaceae. Grassland is absent from sandy-loam soils and these lighter soils are dominated by woodlands of *Eucalyptus*, *Casuarina* and *Callitris*. A large area of grassland was originally present south of Echuca on the Victorian section of the Riverine Plain, but only patches remain (McDougall & Kirkpatrick 1994). Native grasslands on the NSW section of the Riverine Plain are located between Urana in the south-east, Deniliquin in the south-west, Hay in the north-west and Narrandera in the north-east (Fig. 2). This region of native grassland occurrence is covered by eleven, 1:100 000 topographic maps (Fig. 3). Some outlying grassland patches are present on low-lying plains, such as Bullenbong Plain east of Lockhart.

Climate

The region experiences hot summers and cool winters with the summer maximum averaging over 30°C and winter minimum down to 5°C (Fig. 4). The average annual rainfall is about 400 mm in the region. It is wetter in the east with 500 mm at Narrandera, and drier in the west with 408 mm at Deniliquin and 367 mm at Hay. Rainfall peaks in May and September but falls throughout the year, with slightly more in winter and spring (Fig. 4). Summer rainfall comes mainly from storms and is less

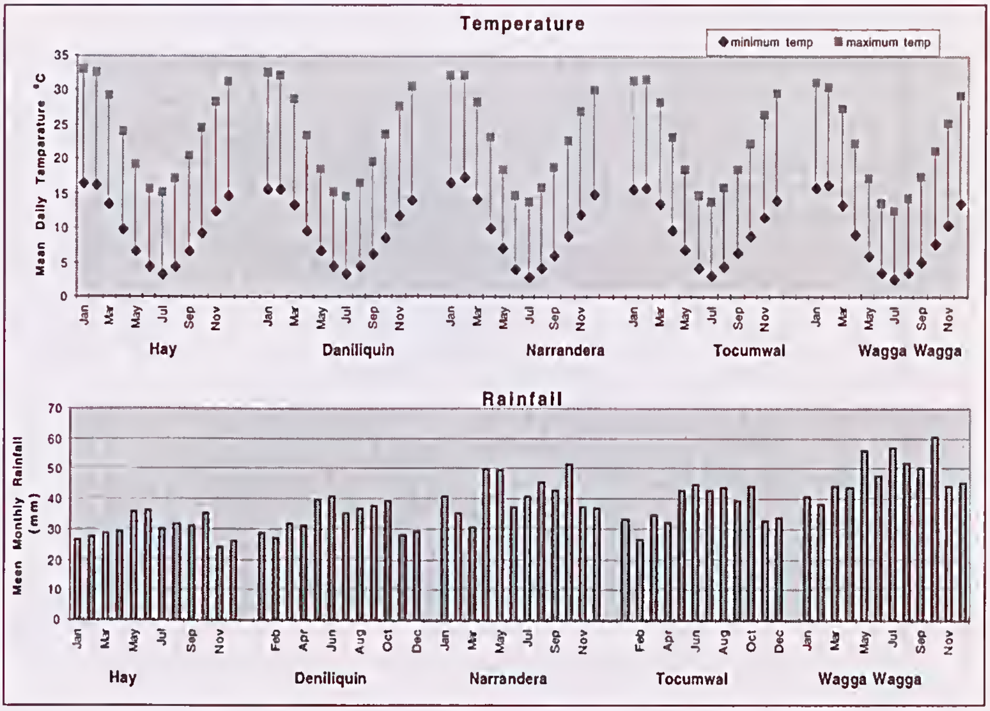

Fig. 4. Average monthly rainfall and temperatures recorded from towns in the study area (Bureau of Meteorology 1996). Rainfall increases from west to east across the Riverine Plain.

reliable than winter rainfall. The evaporation rate is much higher in summer than the cooler months. The main growing, flowering and fruiting period for grasses and forbs is spring, however, some native perennials benefit from summer rainfall.

Geology and soils

The Riverine Plain, situated in the eastern part of the Murray Basin, is bounded by the western slopes of the Great Dividing Range in the east and semi-arid mallee-dominated dune systems to the west. It encompasses the fluvial plains of the Murray, Murrumbidgee, Goulburn and Lachlan Rivers (Butler et al. 1973) and is composed of alluvial deposits of Pleistocene and Recent origin largely derived from prior streams (Butler 1950).

Modern river systems such as Billabong and Yanco Creeks have deposited recent alluvia on the floodplains in the eastern part of the study area. There has been less recent deposition on the Hay Plain on the north-western section of the study area, where its present surface is a relict landform representing the final phase of prior stream deposition (Butler 1958).

Recent stream depositions have given the plains their form, with erosion influencing form to a lesser degree (Butler et al. 1973). The plains have various surface modifications including scalds, channels, drains and depressions (gilgai). Occasional aeolian features such as lunettes and source-bordering sand dunes overlay the alluvial plains.

Grasslands are mainly restricted to red-brown clays and grey-brown clays (Moore 1953a), and do not occur on porous sandy soils of prior stream channels or dunes bordering previous lakes. The red-brown clays occur on slightly elevated, well drained areas and are common in the east and south of the study area. North of Jerilderie, shallow red-brown earths overlay the heavier textured clays (Langford-Smith & Rutherford 1966). Scalding due to wind erosion is a common feature of this soil type. The grey-brown clays occur in depressions where water is retained for a longer period after rain (Butler et al. 1973). The Hay Plain in the north-western section of the study area contains grey cracking clays.

European land use history

Charles Sturt explored the lower Murray River region on two expeditions in 1829 and 1831 (Sturt 1833). In 1836 Thomas Mitchell explored the Lachlan-Murrumbidgee Rivers to the north-east of the study area. The first European settlers arrived in 1832 (Gammage 1986) and by 1840 pastoral runs covered the region. During the 1830s and 1840s there were many confrontations between the settlers and members of the Wiradyuri and Narrungderra Aboriginal people. Disease, combined with oppression by the settlers, quickly led to the social disintegration and population decline of the Aboriginal community (Gammage 1986).

Stock routes were established between townships. Cattle were grazed at first but sheep became more common during the 1860s (Gammage 1986). The region grew wealthy supplying food to the burgeoning population in south-eastern Australia attracted by the gold rushes of the 1850s. Overgrazing and drought affected the region in 1864 (Denny 1992). Dryland cropping commenced in the 1880s and at the same time rabbits invaded the region. Stock numbers peaked between 1887 and 1891, coinciding with further rabbit plagues and invasion by Paterson's Curse (*Echium plantagineum*) (Denny 1992). On visiting the Riverina in 1886, the Government veterinary surgeon, Mr Stanley, commented on the decline of the more valuable indigenous grasses due to 'excessive feeding off' (Mulham 1994). He also commented on the decline of saltbush and cotton bush on the plain

> *... within a generation the plains of lower Riverina were covered with salt and cotton bush and today either of these species of feed are looked upon almost as curiosities. Without doubt they have been fed out of the ground for many miles around Deniliquin, where they once grew in luxuriance ...*
>
> (quoted in Mulham 1994).

By 1920 irrigation had commenced on the Murrumbidgee River floodplain after the construction of the Burrinjuck Dam. In 1930 a drought coincided with the century's worst economic downturn and more rabbit plagues (Denny 1992). After World War II, irrigation increased and large tracts of floodplain country were intensively cropped. The region became Australia's largest irrigated area. Myxomatosis lowered the rabbit population from the 1950s, a time when wool prices and farm profits were high. Since then there have been two major droughts in 1965–67 and 1992–95. Between the 1970s and early 1980s large areas of Bladder Saltbush (*Atriplex vesicaria*) died back on the Hay Plain (Clift et al. 1987). Large wildfires swept the Hay area in 1990 and the Jerilderie area in 1991. Irrigation, particularly for rice farming, is increasing today even in places distant from the rivers. Rising saline water tables present a major threat to agriculture in the region, particularly in irrigated areas (Barson & Barrett-Lennard 1995).

In 1995 the NSW Government brought in a regulation, State Environmental Planning Policy No. 46, to control clearing in NSW. Initially, this included controls on clearing native grasslands, but following lobbying by landholders grassland management plans were compiled by catchment management committees to replace or complement the role of SEPP 46 in native grassland management. The Western Riverina Regional Grassland Management Plan covers our survey area and it sets guidelines for managing native grasslands on private property. This plan is to be regularly reviewed to take into account more information as it comes to hand.

Previous botanical studies

The first recorded comments on the vegetation were from Sturt (1833) where he noted Boree (*Acacia pendula*) and saltbushes near Narrandera, and the open nature of Hamilton Plain near Yanco Creek.

Various aspects of the vegetation of the Riverina, including grassland, have been studied since World War II. Beadle's (1948) map of the vegetation of western New South Wales includes a *Chloris–Danthonia* (Windmill Grass–Wallaby Grass) grassland association extending from the western side of Billabong Creek near Jerilderie to Hay. He mapped the vegetation as he saw it, not how it may have been prior to European settlement. Moore (1953a, 1953b) complemented Beadle's work by describing and mapping the major plant communities eastwards from Billabong Creek on the south western plain to Gundagai on the south western slopes. He suggested that the native grasslands were 'disclimax' communities derived through clearing and grazing of a pre-European woodland that was dominated by the small tree *Acacia pendula* (Myall) and the tall shrub *Atriplex nummularia* (Old Man Saltbush). Some areas would have been predominantly saltbush, others predominantly Myall. The now dominant grasses and forbs would have originally been less common occupying inter-shrub spaces. Moore (1953a) cites supporting evidence for this view from explorers' notes (Sturt 1833), descriptions of properties in early government gazettes, and the survival of *Atriplex nummularia* in lightly grazed horse paddocks on properties such as 'Coonong' and 'Coree'. Beadle (1948) suggested that the grasslands on the eastern edge of the Hay Plain would have once been dominated by *Atriplex vesicaria* (Bladder Saltbush).

Phenological studies by Williams (1961) indicated that most plants on the Riverine Plain flower exclusively in spring (including most exotics) and a group of perennial native species flower in both spring and autumn. He suggested that many of the native perennial species that respond to summer rainfall (with the exception of the opportunistic *Chloris truncata*) have disappeared, or have been reduced in abundance due to the impacts of grazing, and that grazing has favoured plant species that can complete their life-cycle during the wetter months of the year, i.e. between May and October (Williams 1961, 1971). In studying density changes of *Danthonia caespitosa* (and a range of other species) grazed by sheep, Williams (1968, 1969) concluded that a balance had been struck between the composition of the grassland and existing grazing pressure.

Leigh & Noble (1972) presented a coarse-scale vegetation map of the original vegetation of the Riverine Plain. This map does not show the grasslands present today, but instead shows the saltbush-Myall alliance that was proposed to have originally been present. A plant species list for the Riverine Plain was prepared by Leigh & Mulham (1977) with a supplementary list by Mulham & Jones (1981). These lists do not distinguish plant species that are restricted to native grasslands on the Plain, rather they include species recorded from all plant communities in the region.

Porteners (1993) mapped the vegetation of the Hay Plain, which includes the western section of the study area and delineated a White-top Grassland community extending from near Deniliquin to near Gunbar. Maher (1996) surveyed the distribution of the endangered ground bird the Plains Wanderer (*Pedionomus torquatus*) on the Riverine Plain. Based on a limited number of sample sites, McDougall & Kirkpatrick (1994) classified the native grasslands of the Riverine Plain, listed some significant botanical sites and rare species. The native grasslands of the Victorian section of the Riverine Plain have been investigated for their ecological values by Foreman (1995).

Methods

Sampling the native grasslands

Sample sites were selected after field reconnaissance, advice from local experts and landholders, and consultation with the literature on rare species of flora (such as *Swainsona plagiotropis*) and fauna (Plains-wanderer *Pedionomus torquatus*). 1:100 000 LANDSAT TM images helped to define where grassland occurred on the Riverine Plain but it was not possible to confidently delineate different floristic types from these images, for example species-rich native grasslands from species-poor exotic grasslands. Most of the primary and secondary roads were traversed in vehicles, as were many farm roads. This assisted with the selection of sample sites and establishing the distribution of grassland species and grassland communities. The vegetation was sampled at a total of 67 sites, each site being a 10 × 20 m quadrat. Detailed locations of these sites are given in Appendix 1. Twenty-one sites were located in areas identified as Plains-wanderer habitat (Maher 1996). Sampling attempted to cover the geographical distribution of grassland on the Riverine Plain. Exotic grasslands (Benson 1996) were not sampled.

A total of 57 person days were spent in sampling the vegetation. Eighteen sites were sampled in September 1995 and 49 in October 1995. Thus, to maximise species diversity, sampling was concentrated in the peak time for flowering and prior to drying off over summer. The drought in eastern Australia did not effect the Riverina as much as northern NSW and Queensland, nevertheless rainfall was less than the average in 1995 (Bureau of Meteorology pers. comm.).

All plant species were recorded in each quadrat and assigned a cover abundance rating based on a modified Braun-Blanquet 6-point scale (Poore 1955) (<1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–100%). The structure of the vegetation was described by the number, height, cover and dominant species of each layer. The soil type was noted for each site, as was an estimate of the degree and type of disturbance.

Plant species nomenclature conforms with that currently recognised by the National Herbarium of NSW and follows Harden (1990–1993).

Data analysis

All site data were entered into the floristic ecological database Advanced Revelation used at the National Herbarium of NSW. Data were investigated using multivariate techniques available in PATN (Belbin 1993) and other unpublished software (Bedward pers. comm.). The presence/absence of native species were used for analysis as this data set provided maximum information with minimum noise. Analysis of cover data was also undertaken for comparison.

A hierarchical agglomerative classification was used to describe groupings of species and sites (Belbin 1991). The Kulczynski coefficient of dissimilarity was used for its superiority in ecological applications (Belbin 1993). This coefficient describes the dissimilarity between sites based on their shared species composition; it places less emphasis than other coefficients on the absence of species. This is particularly relevant in a rural landscape where species may be absent due to grazing or other past disturbance, rather than due to an inherent likelihood of occurrence. A hierarchical classification of sites was then derived from a clustering strategy using flexible unweighted pair group arithmetic averaging (UPGMA).

To check for misclassified sites in the resultant groups, a checking routine of nearest neighbours (Bedward, unpublished software) was used. This examines the nearest neighbours of all sites (as measured in the association matrix) and assesses whether any given site is grouped with its nearest neighbours. A misclassified site is one in a group where none of that site's nearest neighbours are present, and where none of the other sites in the group has that site as a nearest neighbour.

Once the groupings were finalised, a measure of fidelity to those groupings was generated for each species within that group (Bedward, unpublished software) to elucidate the contribution each species made in defining it. This allowed indicator species to be identified for each plant community.

Results

Floristic composition

A total of 224 species (227 taxa) were recorded during the survey from the 67 grassland sites sampled and areas immediately adjacent. Of these, 58 species (25%) are exotic. The most common families represented were Asteraceae (51 species, 21% exotic), Poaceae (41 species, 38% exotic), Fabaceae–Faboideae (17 species, 65% exotic) and Chenopodiaceae (13 species, 8% exotic).

Rare, threatened or regionally significant plant species

A number of plant species are considered to be significant because they are rare or threatened nationally (Briggs & Leigh 1996), on a state basis (New South Wales or Victoria) or within the region (Table 1). This survey, together with NSW National Herbarium records, revealed that all but one of the six nationally listed species conform with their listing.

Sclerolaena napiformis is very rare having been recorded at only three places near Jerilderie. The survey also confirmed the status of *Swainsona plagiotropis* (Fig. 5) as rare in the region and nationally vulnerable as it was only recorded twice (near 'Coonong' and Jerilderie). Most recent records of this species are from close to the Jerilderie township (Appleby et al. 1991, Chappell & Luke 1994). *Swainsona murrayana*, however, was recorded in 19 sites and commonly observed in the region. While it is threatened in Victoria (Gullan et al. 1990), it is not threatened in NSW. This species should be down-listed from vulnerable to rare or taken off the national list.

Brachycome muelleroides was recorded only once in this survey in a community restricted to swampy places, thus confirming its threat status. *Brachycome papillosa* was not recorded in this survey but has been collected recently in the Jerilderie area and elsewhere in south-western NSW. *Lepidium monoplocoides* is an endangered species that

Table 1. Significant species in the study area showing their rare or threatened status.

National conservation status codes: **3** = species has distribution of over 100 km, **E** = endangered, **V** = vulnerable, **R** = rare, **C** = present in conservation reserve, **a** = considered to be adequately conserved, **i** = considered to be inadequately conserved (Briggs & Leigh 1996). Status in Victoria (Gullan et al. 1990), New South Wales (Schedules 1 & 2 NSW Threatened Species Conservation Act 1995 and authors' opinion) and the region (authors' opinion): **e** = endangered, **v** = vulnerable, **r** = rare, **c** = common.

Species	**Conservation Status**				**Locations**
	Nat'l	**Vic**	**NSW**	**Reg'l**	
Amaranthaceae					
Ptilotus polystachyus		e		v	SWG 3 and adjacent SWG 28
Asteraceae					
Brachycome muelleroides	3VCa	e	v	v	SWG 43
Brachycome papillosa	3V		v	v	Sites 3 & 4 of Chappell & Luke (1994) near Jerilderie
Leptorhynchos elongatus		r	c	r	SWG 17, 18, 49
Leptorhynchos scaber			e	e	Adjacent SWG 43
Microseris lanceolata				e	Adjacent SWG 27
Pogonolepis muelleriana				r	SWG 30
Vittadinia pterochaeta		e		r	SWG 11, 56
Brassicaceae					
Lepidium monoplocoides	3ECi	e	e	e	Adjacent SWG 43
Centrolepidaceae					
Centrolepis glabra				r	SWG 43
Chenopodiaceae					
Chenopodium desertorum subsp. *virosum*			c	r	SWG 7, 48, 54, 55, 60
Sclerolaena napiformis	3E	v	e	e	South Coree Road east of SWG 24 and sites 13 and 16 of Chappell & Luke (1994)
Cyperaceae					
Isolepis congrua		v	c?	r	SWG 67
Fabaceae–Faboideae					
Swainsona murrayana	3VCi	e	v	c	SWG 4, 6, 7, 8, 12, 13, 14, 20, 24, 27, 28, 29, 30, 32, 38, 41, 45, 46, 55 & adjacent SWG 1 & 19
Swainsona plagiotropis	3VCi	e	v	v	Sites 4, 8 & 22 of Chappell & Luke (1994)
Swainsona swainsonioides		e	c?	v	Adjacent SWG 12

Species	**Conservation Status**				**Locations**
	Nat'l	**Vic**	**NSW**	**Reg'l**	
Orchidaceae					
Diuris dendrobioides				r	Adjacent SWG 3
Diuris lanceolata				r	Adjacent SWG 3
Poaceae					
Eulalia aurea		c	c	v	SWG 9
Themeda australis		c	c	e	SWG 3 and near SWG 9
Astrebla lappacea		c	c	r	'South Burrabogie' 30 km SE of Hay

has been eliminated by grazing throughout its range. During the survey it was recorded only once. It has also been recently recorded in the Urana Nature Reserve (E. Whiting pers. comm.).

Leptorhynchos scaber (Asteraceae) warrants listing under the NSW Threatened Species Conservation Act (Schedule 1) as an endangered species. The collection from this survey is the first from NSW. It is also restricted in Victoria (P. Foreman pers. comm.) but is not on the national list because of its abundance in Western Australia. There is, however, the possibility that the Western Australian taxon may be different as it grows in a different habitat.

Some species are significant on a regional basis even though they may be common elsewhere. The grasses *Themeda australis* and *Eulalia aurea* (Fig. 6) were recorded once during the survey and are rare in the region having been grazed out over the last 150 years. Other palatable species, such as *Microseris lanceolata*, *Swainsona swainsonioides* and several species of orchids have also been depleted.

Several species listed by Gullan et al. (1990) as rare in Victoria are common in the study area. These include *Sporobolus caroli*, *Stipa setacea*, *Eleocharis pallens*, *Maireana aphylla*, *Maireana excavata*, *Leucochrysum molle*, *Leptorhynchos panaetioides* and *Brachycome chrysoglossa*.

Data analysis

The resulting dendrogram from the Kulczynski association and UPGMA clustering analysis (adjusted for misclassification) is shown in Fig. 7. Six grassland communities were defined at a dissimilarity measure of 0.75. Communities 1a and 1b are closely allied and share many species. Community 5 is most distinct. Community 2 (site 3) is also distinct as it contained many woodland species not recorded in other sites. When the analysis was run using cover data, the grassy woodland at site 3 clustered with site 1 at 'Morundah' in Community 1a. These sites share a number of species including an abundance of *Lomandra effusa*.

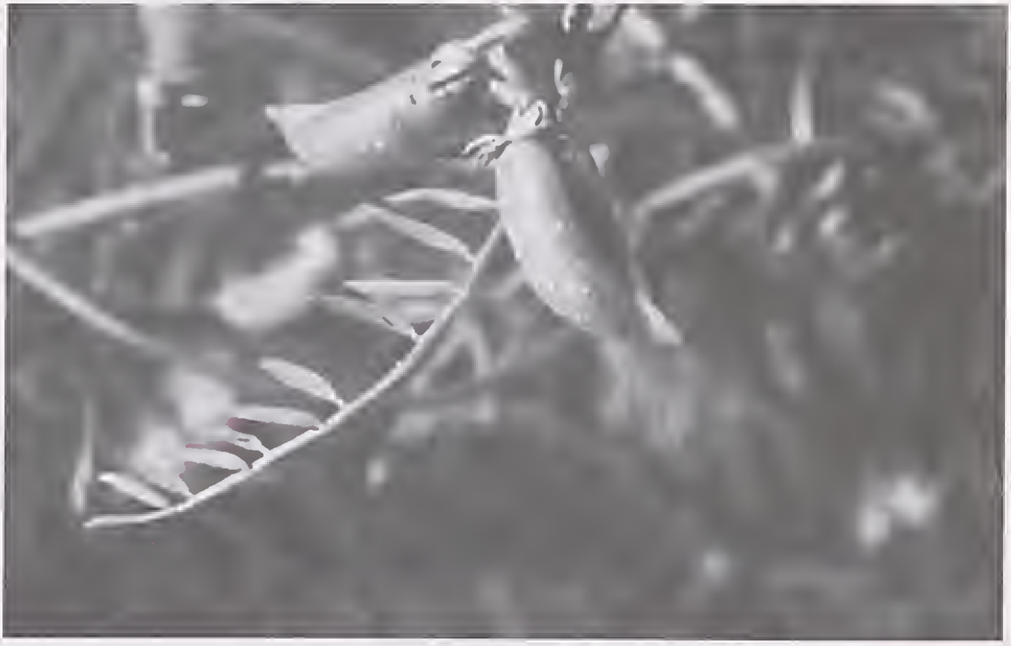

Fig 5. Seed pods of the nationally vulnerable *Swainsona plagiotropis*. Surveys since 1991 indicate that this species is mainly restricted to the Jerilderie district. A species recovery plan has been prepared for the species. Photo: J. Benson.

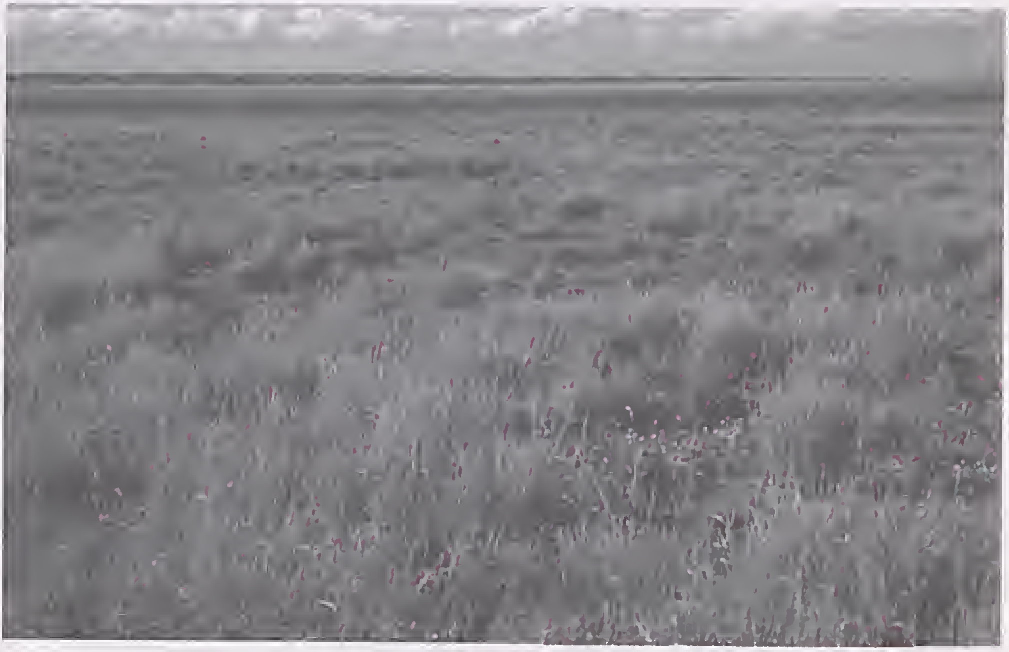

Fig. 6. *Eulalia aurea* and *Themeda australis* are now rare in the region, surviving in lightly grazed areas such as SWG 9 on 'Coonong'. Photo: M. Porteners.

Plant communities

A relatively large area of native grassland remains on the Riverine Plain, albeit as a derived native grassland, compared with other temperate grassland regions in south eastern Australia (McDougall & Kirkpatrick 1994). Based on the findings of Foreman (1995), it would appear the NSW section of the Riverine Plain contains larger areas of native grassland than that remaining on the Victorian section of the Riverine Plain.

Communities 1a and 1b are the most abundant native grassland communities in the study area and tend to be more species-rich than Communities 4 or 5 (Table 2). Community 1a is centred on Jerilderie and Urana, while the closely allied Community 1b mainly occurs in the vicinity of Deniliquin. Community 2 was sampled once only and occurs on sandy rises near Urana. Community 3 mainly occurs in the eastern section of the region. Community 4 occurs in the drier north-western section of the study area and Community 5 is scattered over the study area but restricted to more

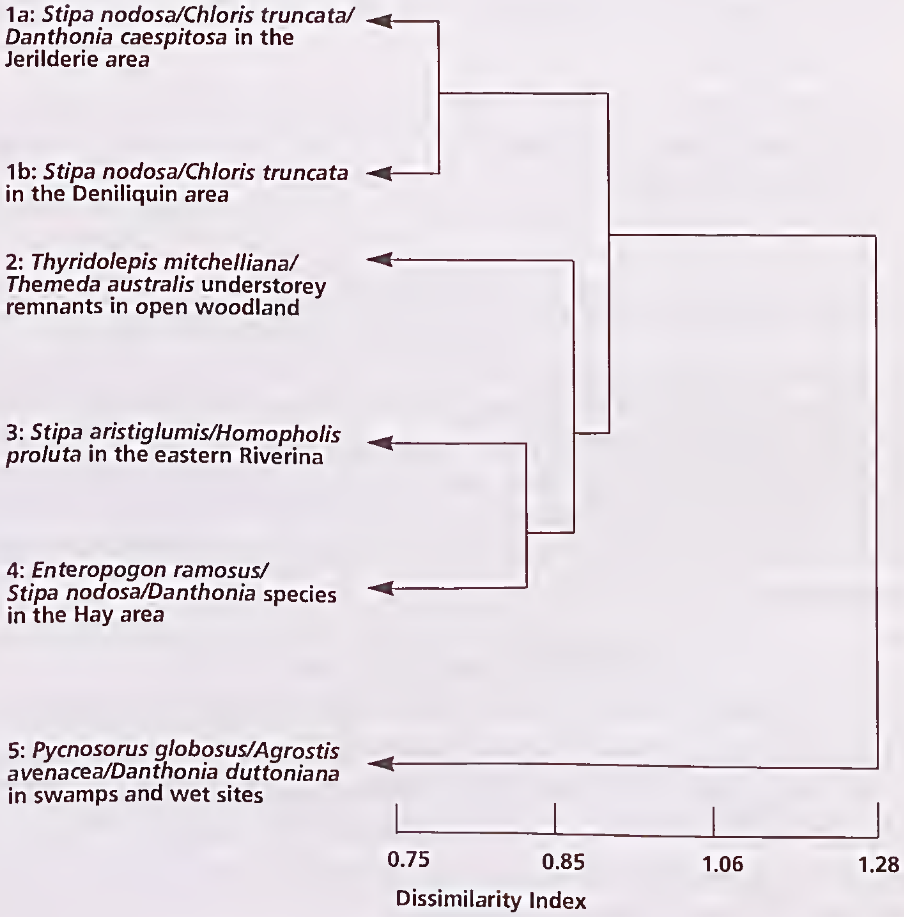
1a: *Stipa nodosa/Chloris truncata/ Danthonia caespitosa* in the Jerilderie area
1b: *Stipa nodosa/Chloris truncata* in the Deniliquin area
2: *Thyridolepis mitchelliana/ Themeda australis* understorey remnants in open woodland
3: *Stipa aristiglumis/Homopholis proluta* in the eastern Riverina
4: *Enteropogon ramosus/ Stipa nodosa/Danthonia* species in the Hay area
5: *Pycnosorus globosus/Agrostis avenacea/Danthonia duttoniana* in swamps and wet sites
0.75
0.85
1.06
1.28
Dissimilarity Index

Fig. 7. Dendrogram showing five plant communities produced from Kulczynski association and UPGMA clustering.

Table 2. Grassland communities of the Riverine Plain (NSW).

Comm.	Main Grass Species	Distribution	No. Sites	Total No. Species	No. Native Species	No. Exotic Species(%)
1a	*Stipa nodosa* *Chloris truncata* *Danthonia caespitosa*	Jerilderie area	24	130	91	39 (30%)
1b	*Stipa nodosa* *Chloris truncata*	Deniliquin area	17	104	74	30 (29%)
2	*Thyridolepis mitchelliana* *Themeda australis* *Danthonia eriantha*	West of Lake Urana	1	48	41	7 (15%)
3	*Stipa aristiglumis* *Homopholis proluta*	Eastern Riverina	7	100	71	29 (29%)
4	*Enteropogon ramosus* *Stipa nodosa* *Danthonia* spp.	Hay area	15	79	57	22 (28%)
5	*Agrostis avenacea* *Danthonia duttoniana*	Scattered	3	50	37	13 (26%)

poorly drained sites. Some of the communities share a high proportion of species, others are more distinct, for example, Community 5 (see Appendix 2).

The numbers of exotic species vary within each community from site to site depending on past land use. At the time of sampling, Wimmera Ryegrass (*Lolium rigidum*) was the most common and widely distributed exotic grass. Cape Weed (*Arctotheca calendula*) was one of the most abundant exotic forbs in early spring, but had substantially died off by early summer. This highlights the importance of the timing of a survey as grassland floristic composition varies with the seasons and in response to different rainfall patterns.

Description of grassland communities

The five communities defined in the classification analysis are described below and summarised above in Table 2. The sites classified into each community are listed. Full location information of all sites is given in Appendix 1. The total and mean number of native and exotic species (+/- standard deviation) per 10 × 20 m plot is also shown.

Indicator species are those species that occurred in more than 40% of the sites in a community and were rarely or never found in another community (had a fidelity measure of more than 0.8 as calculated by fidelity analysis, Bedward unpublished software). **Dominant** grass species and other **common** species are those that occurred in more than 50% of the sites per community, and are listed in descending order of frequency. The percent frequencies for each species within each community and overall are shown in Appendix 2.

Community 1a

Stipa nodosa–Chloris truncata–Danthonia caespitosa **Jerilderie area** (Fig. 8) (similar to Community R1.2 in McDougall & Kirkpatrick 1994)

Landform, geology and soils: Level plains in the southern Riverine Plain, mainly on grey-brown cracking clay to red-brown, often scalded clay.

Distribution: Throughout the Jerilderie area, particularly south-west to north-east of Jerilderie.

Sample sites: 1, 2, 4, 7, 13, 14, 21, 25, 26, 27, 28, 29, 30, 31, 32, 38, 40, 42, 45, 56, 59, 60, 64, 66 (n=24)

Structure: Open to mid-dense, tussock grassland (with herbaceous ground layer).

Dominant native grass species: *Stipa nodosa, Chloris truncata, Danthonia caespitosa.*

Indicator species: *Brachycome chrysoglossa, Wahlenbergia gracilenta, Isoetopsis graminifolia.*

Other common native species: *Maireana pentagona, Triptilodiscus pygmaeus, Rhodanthe corymbiflora, Chrysocephalum apiculatum, Sida corrugata, Goodenia fascicularis, Daucus glochidiatus, Maireana excavata, Wurmbea dioica* subsp. *dioica, Hyalosperma glutinosum* subsp. *glutinosum, Ptilotus exaltatus* var. *exaltatus, Goodenia pusilliflora, Myriocephalus rhizocephalus, Calocephalus sonderi, Oxalis perennans, Crassula colorata, Asperula conferta.*

Common exotic species: *Hypochaeris glabra, Lolium rigidum, Arctotheca calendula, Medicago truncatula, Cotula bipinnata, Romulea rosea.*

Total no. native species: 91

Total no. exotic species: 39

Mean no. native species per site: 26 +/- 6

Mean no. exotic species per site: 9 +/- 3

Condition: Many of the sample sites had been moderately to heavily grazed and contain a high proportion of weeds. Several sites however, are in excellent condition, having a high native species diversity and density. Many areas once occupied by this community have been 'improved' and are dominated by exotic pasture species.

Threats and conservation status: This community is currently not represented in the conservation reserves, with large areas under freehold management. Several important sites are situated on travelling stock routes (TSRs). Increased grazing pressure, weed invasion and clearing for agriculture are the main threats. Sites 1, 13, 21, 26, 28, 29, 30, 42, 60 and 64 are known habitat for the Plains-wanderer (Maher 1996) (see Table 4).

Key sites for conservation: Site 1 in Boree paddock on the property 'Morundah', owned by the Australian Navy (Fig. 14). This paddock contained an excellent stand of this community, rich in native species including the endangered forbs *Lepidium monoplocoides* and *Leptorhynchos scaber*. This was the first substantiated NSW record of *Leptorhynchos scaber*. The area also contains important remnants of Community 5 (site 43). Other significant sites include 4, 13, 14, and 21 that are all species-rich and most contain rare or threatened species. Site 4 contains a population of the vulnerable species *Swainsona plagiotropis*. Other *Swainsona plagiotropis* populations have been recorded in this community in the past (Chappell & Luke 1994, Appleby et al. 1991). The vulnerable plant *Swainsona murrayana* was recorded at half of the sites sampled in this grassland community (1, 4, 7, 13, 14, 27, 28, 29, 30, 32, 38, 45) indicating it is not threatened nor rare on the NSW section of the Riverine Plain.

Community 1b

Stipa nodosa–Chloris truncata **Deniliquin** area (Fig. 9)

Sample sites: 12, 15, 16, 19, 20, 22, 24, 36, 44, 46, 48, 50, 52, 53, 54, 55, 65 (n=17).

Landform, geology and soils: Floodplains and level plains in the southern Riverine Plain, mainly on grey cracking clay to red-brown loamy clay.

Distribution: Throughout the Deniliquin area, particularly north to north-east of Deniliquin with outliers around Jerilderie.

Structure: Open to mid-dense, tussock grassland (with herbaceous ground layer).

Dominant native grass species: *Stipa nodosa, Chloris truncata.*

Indicator species: *Leucochrysum molle.*

Other common native species: *Rhodanthe corymbiflora, Daucus glochidiatus, Maireana pentagona, Sida corrugata, Calotis scabiosifolia* var. *scabiosifolia, Chrysocephalum apiculatum, Leptorhynchos panaetioides, Goodenia fascicularis, Calocephalus sonderi, Maireana excavata, Goodenia pusilliflora, Chamaesyce drummondii.*

Common exotic species: *Lolium rigidum, Medicago truncatula, Arctotheca calendula, Cotula bipinnata, Hypochaeris glabra, Avena fatua, Romulea rosea, Echium plantagineum.*

Total no. native species: 74

Total no. exotic species: 30

Mean no. native species per site: 21 +/- 3

Mean no. exotic species per site: 8 +/- 2

Condition: Many sites have been moderately grazed and contain a high proportion of weeds. Most of the areas were of average to good condition with only one site judged as being in excellent condition. Many areas once occupied by this community have been 'improved' and are dominated by introduced pasture species.

Threats and conservation status: This community is currently not conserved with large areas under freehold management and on travelling stock routes (TSRs). Increased grazing pressure, weed invasion and clearing for agriculture are the main threats. Sites 15, 16, 52 and 53 are known habitat for the Plains-wanderer (Maher 1996) (see Table 4).

Key sites for conservation: Site 24 on South Coree Road near Jerilderie is in a TSR that contains one of only three known records in NSW of the vulnerable shrub *Sclerolaena napiformis*. The paddock immediately west of Jerilderie, sampled by Appleby et al. (1991) and J. Benson in October 1991, contains one of the largest populations of *Swainsona plagiotropis* and is a nature reserve proposal.

Community 2

***Thyridolepis mitchelliana–Themeda australis* understorey remnants in open woodland** (Fig. 10)

Landform, geology and soils: Elevated plains and low rises of red to red-brown clay to clay-loam soils, in a range of woodland communities.

Distribution: Very scattered and occasional occurrences throughout the south-eastern Riverina; most notable remnant in a small triangular paddock west of Lake Urana.

Sample site: 3 (n=1)

Structure: Mid-dense tussock grass understorey in open woodland.

Dominant native grass species: *Thyridolepis mitchelliana, Themeda australis, Danthonia eriantha, Stipa eremophila, Stipa setacea, Aristida jerichoensis* var. *jerichoensis, Monochather paradoxa.*

Indicator species (exclusive to this group): *Thyridolepis mitchelliana, Themeda australis, Stackhousia monogyna, Callitris glaucophylla, Allocasuarina verticillata, Stipa eremophila, Hakea tephrosperma, Drosera glanduligera, Eremophila longifolia, Levenhookia dubia, Pimelea micrantha, Minuria leptophylla, Thysanotus patersonii, Ptilotus polystachyus* var. *polystachyus, Cynoglossum suaveolens, Prasophyllum campestre, Aristida jerichoensis* var. *jerichoensis, Monochather paradoxa, Diuris lanceolata, Diuris dendrobioides, Dianella longifolia* var. *porracea.*

Other common native species: *Chrysocephalum apiculatum, Hyalosperma semisterile, Bulbine bulbosa, Lomandra effusa, Hyalospermum glutinosum* subsp. *glutinosum, Cheilanthes sieberi* subsp. *sieberi, Wahlenbergia stricta* subsp. *alterna, Actinobole uliginosum, Wahlenbergia luteola.*

Common exotic species: *Trifolium arvense, Aira elegantissima, Erodium crinitum, Hypochaeris glabra, Avena fatua, Arctotheca calendula, Romulea minutiflora, Parentucellia latifolia.*

Total no. native species: 41

Total no. exotic species: 7

Condition: The site sampled is in excellent condition and has been fenced off from grazing for some time. The understorey is dense and contains a high proportion of native species including *Stackhousia monogyna*, uncommon grasses and three orchid species. *Themeda australis* is now vulnerable in the Riverina Plain, being recorded only once during this survey.

Threats and conservation status: *Themeda australis* is now depleted on the Riverine Plain and remains poorly conserved, with remnants under freehold management. The

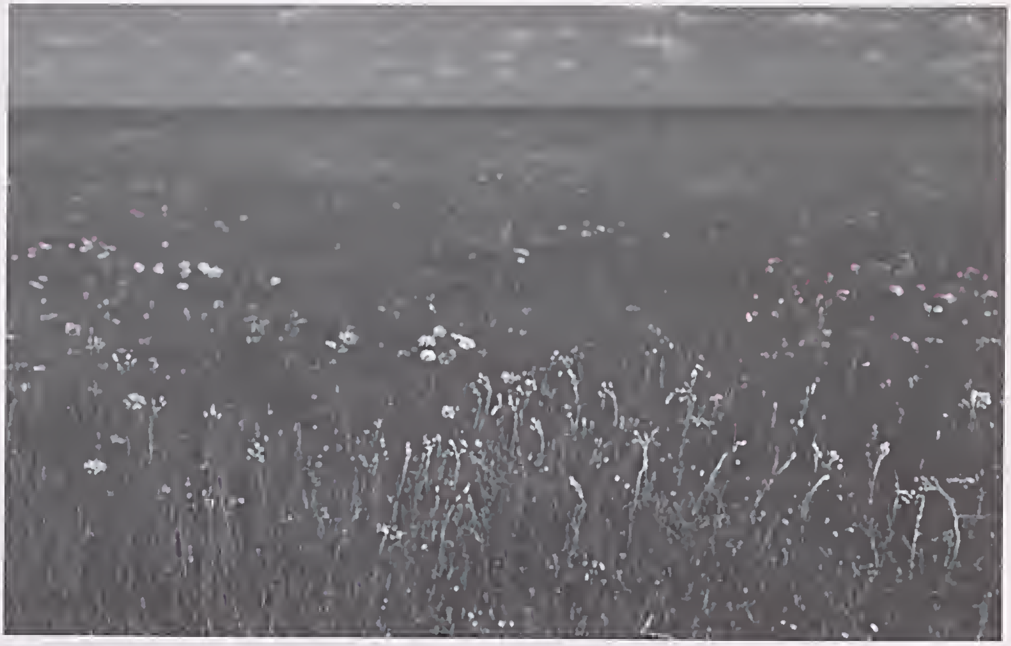

Fig. 8. A species-rich grassland in Community 1a dominated by *Danthonia linkii* var. *linkii*, *Stipa nodosa*, *Swainsona murrayana*, *Calotis scabiosifolia* var. *scabiosifolia* and *Brachycome chrysoglossa* on a travelling stock reserve adjacent to Hynes Lane, west of Jerilderie (site SWG 14). Photo: M. Porteners.

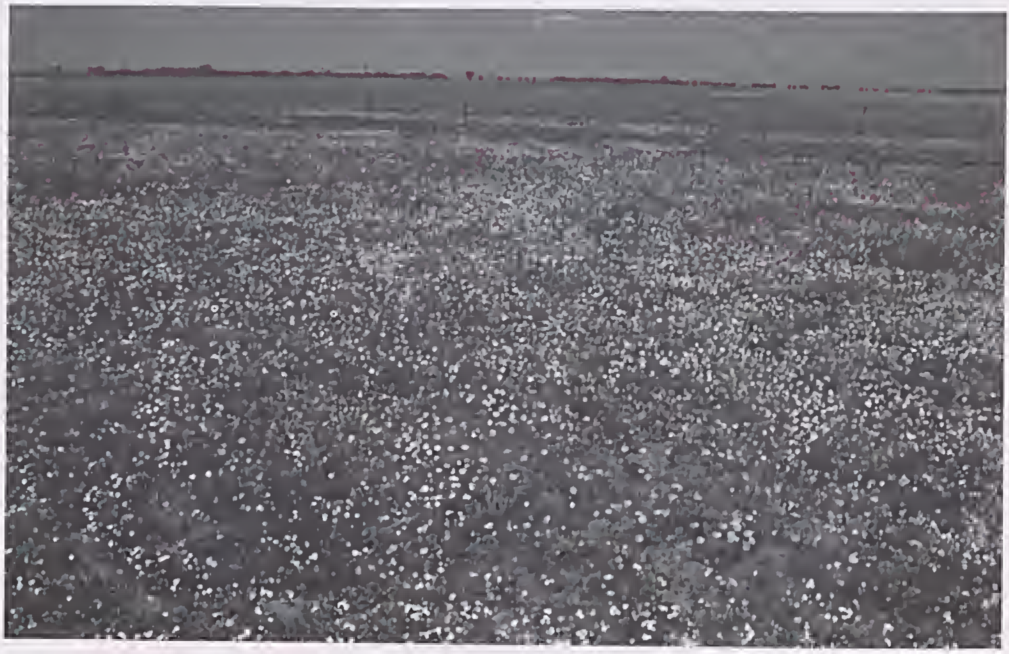

Fig. 9. Community 1b at SWG 12, McLennons Bore Road north of Jerilderie dominated by *Rhodanthe corymbiflora*, *Stipa nodosa*, *Cotula bipinnata* and *Leucochrysum molle*. Photo: M. Porteners.

nature of the remaining populations suggest *Themeda* was more abundant before grazing pressure increased, although this species may not have ever been as abundant in this region as in other grassland and grassy woodland areas in southern Victoria and eastern NSW.

Key sites for conservation: Site 3 is a small fenced-off corner of a paddock west of Lake Urana on 'Cocketgedong Farm'. Its ground cover is in excellent condition with a dense *Thyridolepis mitchelliana, Themeda australis* and *Danthonia eriantha* sward with very few weeds and many uncommon native herb species (such as orchids). This is a significant site of high species diversity and with a history of relatively low grazing intensity. It is a reference site warranting protection, as it has not been subject to stock grazing for decades (M. Driver pers. comm.).

Community 3

Stipa aristiglumis–Homopholis proluta **eastern Riverina** (Fig. 11)

Landform, geology and soils: Level to depressed plains and floodplains, in the eastern Riverine Plain, on grey to dark brown, self-mulching clayey soils.

Distribution: Throughout the eastern portion of the study area, north-east to south-east of Jerilderie.

Sample sites: 5, 6, 8, 9, 39, 63, 67 (n=7)

Structure: Open to dense, tall tussock grassland.

Dominant native grass species: *Stipa aristiglumis, Homopholis proluta.*

Indicator species: *Calotis anthemoides, Rumex dumosus, Arthropodium minus, Stipa aristiglumis, Asperula conferta, Leptorhynchos squamatus* subsp. A.

Other common native species: *Wurmbea dioica* subsp. *dioica, Crassula decumbens* var. *decumbens, Maireana pentagona, Goodenia fascicularis, Rhodanthe corymbiflora, Oxalis perennans, Enteropogon ramosus.*

Common exotic species: *Arctotheca calendula, Hypochaeris glabra, Lolium rigidum, Trifolium arvense, Romulea rosea, Echium plantagineum, Medicago truncatula.*

Total no. native species: 71

Total no. exotic species: 29

Mean no. native species per site: 21 +/- 7

Mean no. exotic species per site: 10 +/- 3

Condition: Most sites contain a high proportion of weeds because they are water and nutrient sinks, and have been moderately to heavily grazed. Some sites are in good condition with a high density of native grasses.

Threats and conservation status: This community is currently not conserved and most sites are under freehold management with weed invasion and increased grazing pressure the main threats. Sites 8, 9 and 63 are habitat for the threatened Plains-wanderer (Maher 1996) (see Table 4).

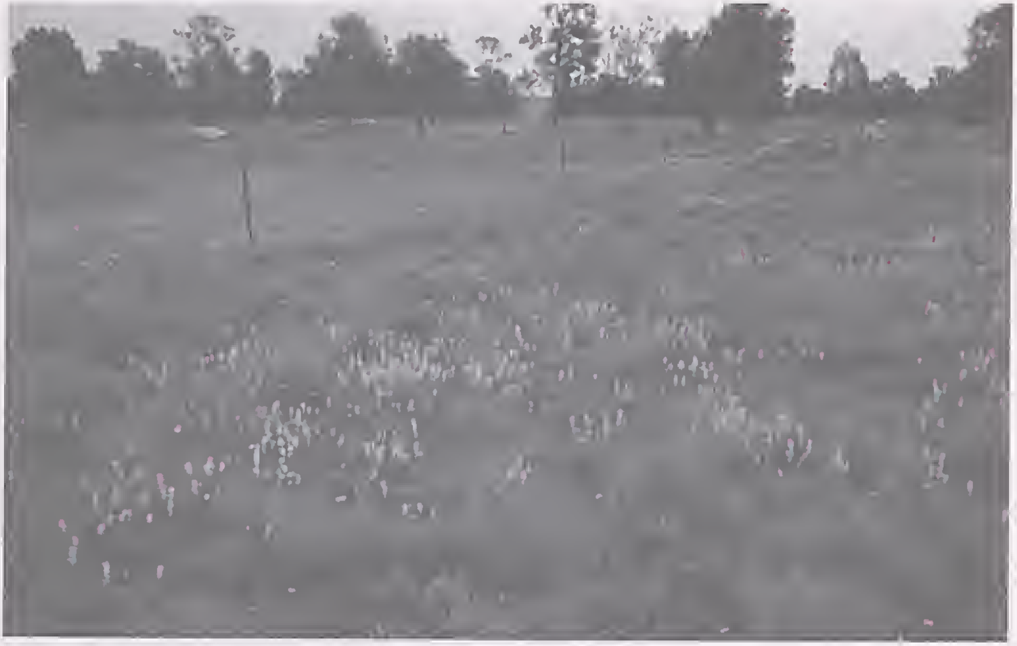

Fig. 10. *Thyridolepis mitchelliana* and *Stackhousia monogyna* dominant at SWG 3 in Community 2, near the 'Cocketgedong Farm', west of Lake Urana. This site has been fenced off for decades and contains a number of significant plant species including Kangaroo Grass, *Themeda australis*, which is now rare in the region. Photo: M. Porteners.

Fig. 11. SWG 39 in Community 3 is dominated by Plains Grass *Stipa aristiglumis*. This community mainly occurs in the eastern section of the region mostly on grey clays in low lying areas. Photo: J. Benson.

Key sites for conservation: Sites 6, 8, 9 and 67. Site 8 contains a population of the vulnerable pea *Swainsona plagiotropis* some distance from most of the other populations of this species.

Community 4

***Enteropogon ramosus–Stipa nodosa–Danthonia* species in the Hay area** (Fig. 12)

Landform, geology and soils: Level plains, in the western to south-western Riverine Plain, on grey cracking clay to red-brown clay.

Distribution: Throughout the western portion of the study area, near Hay and north-east of Deniliquin.

Sample sites: 10, 11, 17, 18, 33, 34, 35, 37, 47, 49, 51, 57, 58, 61, 62 (n=15)

Structure: Mid-dense to dense, tussock grassland.

Dominant native grass species: *Enteropogon ramosus, Stipa nodosa* (one or more species of *Danthonia* were always present at the site).

Indicator species: No indicator species.

Other common native species: *Rhodanthe corymbiflora, Crassula colorata* var. *acuminata, Sida corrugata, Atriplex leptocarpa.*

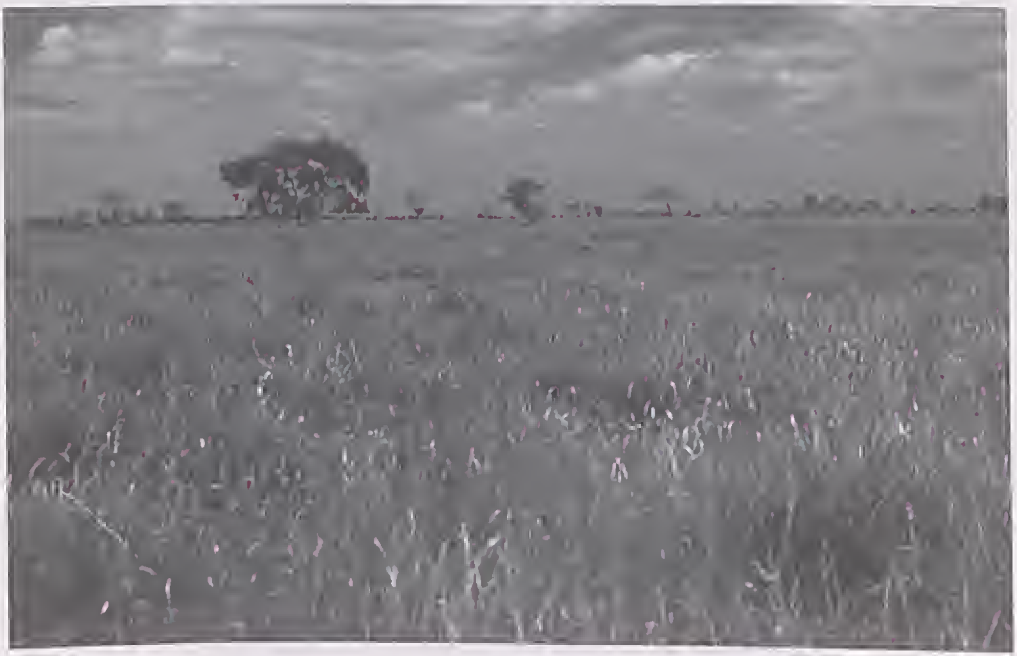

Fig. 12. SWG 37 in Community 4 on 'Cooinbil', dominated by *Stipa nodosa, Danthonia eriantha, Enteropogon ramosus* and the introduced Wimmera Ryegrass *Lolium rigidum.* This community is mainly confined to the western section of the study area. Photo: M. Porteners.

Common exotic species: *Lolium rigidum, Avena fatua, Medicago truncatula, Arctotheca calendula, Echium plantagineum, Cotula bipinnata, Erodium cicutarium.*

Total no. native species: 57

Total no. exotic species: 22

Mean no. native species per site: 15 +/- 4

Mean no. exotic species per site: 8 +/- 2

Condition: Most sites are of average to poor condition, contain a high proportion of weeds (mostly naturalised pasture grasses), and have been moderately grazed.

Threats and conservation status: This community is currently not conserved and most sites are under freehold management with weed invasion and increased grazing pressure the main threats. Site 49 is known habitat for the Plains-wanderer (Maher 1996) (see Table 5).

Key sites for conservation: Most sites sampled in this community are species poor and contain a high proportion of exotic species. Few sites can be singled out for special conservation action. Site 47 on Warwillah Road was noted as being in excellent condition and contains substantial clumps of *Danthonia linkii* var. *fulva*.

Community 5

***Pycnosorus globosus–Agrostis avenacea–Danthonia duttoniana* in swamps and wet sites** (Fig. 13) (similar to to Community R1.3 in McDougall & Kirkpatrick 1994)

Landform, geology and soils: Depressions, swamps and low-lying plains, on grey cracking clay.

Distribution: Throughout the study area.

Sample sites: 23, 41, 43 (n=3)

Structure: Mid-dense to dense, tussock grassland.

Dominant native grass species: *Agrostis avenacea, Danthonia duttoniana, Eragrostis australasica, Homopholis proluta.*

Indicator species: *Marsilea drummondii, Myriophyllum crispatum, Eragrostis australasica, Eleocharis pallens, Agrostis avenacea, Danthonia duttoniana, Pycnosorus globosus, Swainsona procumbens, Juncus radula, Ranunculus pentandrus* var. *platycarpus.*

Other Common native species: *Myriocephalus rhizocephalus, Teucrium racemosum, Crassula decumbens* var. *decumbens.*

Common exotic species: *Alopecurus geniculatus, Arctotheca calendula, Cotula bipinnata, Lolium rigidum, Juncus articulatus.*

Total no. native species: 37

Total no. exotic species: 13

Mean no. native species per site: 19 +/- 5

Mean no. exotic species per site: 6 +/- 5

Condition: Two of the sites sampled are in excellent condition and are significant wet-grassland areas containing rare and unusual species and few weeds. The other site had been burnt and grazed. Many floodplains and depressions across the Riverine Plain once containing this community have been cleared for irrigation and cropping.

Threats and conservation status: Clearing, overgrazing and pugging by stock appear to be the main threats to this community which is currently not conserved with most sites under freehold management.

Key sites for conservation: Site 43 on 'Morundah' is a significant wetland-grassland community containing the vulnerable species *Brachycome muelleroides*. Other uncommon or unusual plants recorded in this community include *Myosurus minimus* var. *australis, Utricularia dichotoma, Centrolepis glabra, Isolepis hookeriana, Isolepis victoriensis* and *Triglochin procerum*.

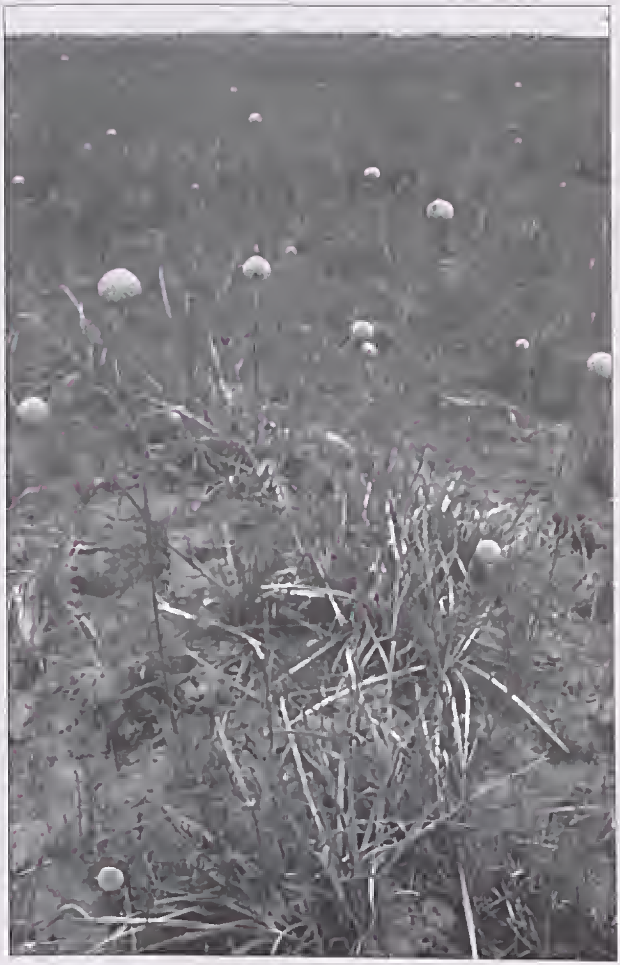

Fig 13. SWG 41 along the Narrandera-Urana Road in Community 5 dominated by *Pycnosorus globosus, Danthonia caespitosa, Agrostis avenacea* and *Juncus radula*. This community is confined to poorly drained, low lying areas. Photo: J. Benson.

Grassland sites of botanical significance on the Riverine Plain

Seven criteria were used to determine the significance of the sample sites (see Table 3) including presence of significant species, diversity, condition and management options. Of the 67 plots surveyed, 15 were designated as containing features warranting listing as sites of botanical significance. The presence of significant plant species was most heavily weighted in defining these. In addition to these sites, we consider that all of the previous recorded locations of *Swainsona plagiotropis* should also rank as sites of significance.

Sampling covered only a small proportion of the landscape and did not cover every farm or every paddock (although most of the roads were traversed and previous information on the grasslands was used to refine the sampling). It is likely that other important sites exist. The significant sites listed in Table 3 should, therefore, be considered only as a starting point in regional assessments of grassland sites of significance.

The most widespread Communities 1a and 1b, centred on Jerilderie, Urana and Deniliquin, account for the majority of the sites listed. These communities are species rich and contain most of the ROTAP and other significant plant species recorded during the survey or by previous studies. Site 3 in Community 2 is floristically distinct, containing many species that were not recorded elsewhere. This is because it has been fenced off from stock for several decades and it is situated on a sandy rise unlike other sites. Community 4 was found to contain fewer significant species and a lower species richness than Communities 1a and 1b. It also had a relatively high number and cover of exotic species, with Wild Oats (*Avena fatua*) and Wimmera Ryegrass (*Lolium rigidum*) dominant in places.

Some properties are important for the protection of significant sites. They include parts of the properties 'Coonong' and 'Cocketgedong', and a section of 'Morundah' now owned by the Australian Navy (Figure 14), which appear not to have been over-grazed or over-improved in the past. Similarly, 'Invermay' near Urana and 'Boonoke' near Conargo have been lightly grazed. 'Invermay' contained unusually tall and dense Plains Grass (*Stipa aristiglumis*). 'Boonoke' had extensive stands of Community 1b and regular records of Plains-wanderers. However, these areas are not nominated as special as no significant plant species were found.

Relationship of native grassland with Plains-wanderer sites

The Plains-wanderer is the monotypic representative of the Pedionomidae and is endemic to Australia. It is a cryptic, ground-dwelling bird that, despite its common name, is sedentary if the habitat remains suitable (Marchant & Higgins 1993). The biology, conservation and management of the endangered Plains-wanderer have recently been addressed by Baker-Gabb (1987, 1988, 1990), Baker-Gabb et al. (1990), Harrington et al. (1988) and Maher (1996).

Table 3. Grassland sites of botanical significance in the southern Riverina.

Tenure: **P** = private land, **TSR** = travelling stock reserve/route. Justification: **T1** = contains rare or threatened plant species; **T2** = contains rare or threatened animal species; **U** = contains uncommon or regionally rare taxa; **C** = is in relatively good/excellent condition (low ratio of weeds: natives, lack of major disturbance); **M** = is well fenced or easy to manage in other ways; **D** = contains a high diversity of native plant species; **E** = outstanding example of a plant community. Recommended Management: **LG** = light intermittent grazing based on past land use; **F** = fencing of site as protection from grazing; **W** = weed control of major concern; **R** = monitoring/research of populations of rare species. Note: *Swainsona murrayana* was not considered a T1 species because it was found to be common in the region. Only a proportion of the Plains-wanderer sites delineated by Maher (1996) are listed, being those recorded in good condition or containing significant plant species.

Site	**Comm.**	**Location (tenure)**	**Justification**	**Recommended Management**
SWG 1	1a	'Morundah' (Navy)	T1,T2,U,C,M,D,E	F,R
SWG 4	1a	Urana–Jerilderie Rd (TSR)	T1	LG,R
SWG 13	1a	Bundure Rd (Airstrip)	T2,C,D,M	LG,R
SWG 14	1a	Hynes Lane (TSR)	T1,C,D	LG,R
SWG 21	1a	'Cocketgedong' (P)	T2,C,D	LG,R
SWG 28	1a	'Coonong' (P)	T2,U,D	LG
SWG 24 (adj.)	1b	Hynes Lane (TSR)	T1,E	LG,R
Council block west of Jerilderie	1b	Pn 3, Ph Jerilderie Co Urana (Jerilderie Shire Council)	T1, U,C,M,D,E	LG,R
All *Swainsona plagiotropis* sites	Probably 1a and 1b	Jerilderie area (see Chappell & Luke '94 and Appleby et al. '91)	T1	LG,R
SWG 3	2	'Cocketgedong' (P)	U,M,D,E	F,R
SWG 6	3	Bullenbong Plain (Road Reserve)	U,E	LG,W
SWG 8	3	'Coonong' (P)	T1,T2,U,D	LG,W,R
SWG 9	3	'Coonong' (P)	T2,C,U,E	LG
SWG 67	3	Bullenbong Plain (Road Reserve)	U,E	W,LG
SWG 47	4	Warwillah Rd (P)	C,E	LG,W
SWG 43	5	'Morundah' (Navy)	T1,U,C,D,E	F,R
SWG 41	5	Narrandera–Urana Rd (Road Reserve)	T1,U,C,D,E	F,R

Historically, the Plains-wanderer was formerly widespread and common across the Darling Downs, the slopes and tablelands of NSW (including around Sydney), South Gippsland and west across Victoria to the Adelaide Plains (Marchant & Higgins 1993).

Its distribution has contracted markedly and its abundance declined as agriculture has intensified (Baker–Gabb et al. 1990). In NSW, it is now found regularly only in the Riverina, and Willandra National Park (north-east of Hillston) is the only reserve known to contain the species (Baker–Gabb 1990).

Baker-Gabb (1990) defined suitable habitat for Plains-wanderers as sparse native grassland on soils that do not support dense pasture growth under any seasonal conditions. Specifically, he characterised the grassland as having:

- about 50% bare ground, with no more than 10% leaf litter;
- two layers of vegetation with most (94%) in the lower layer;
- the lower layer less than 5 cm in height;
- the upper layer rarely exceeding 5 cm in height with tussocks spaced between 10–20 cm.

It is assumed that this structure allows for easy foraging and offers adequate concealment from predators.

Twenty one of the 67 sample sites coincided with areas identified by Maher (1996) as Plains-wanderer habitat. Table 4 lists these sites, the type of Plains-wanderer habitat as

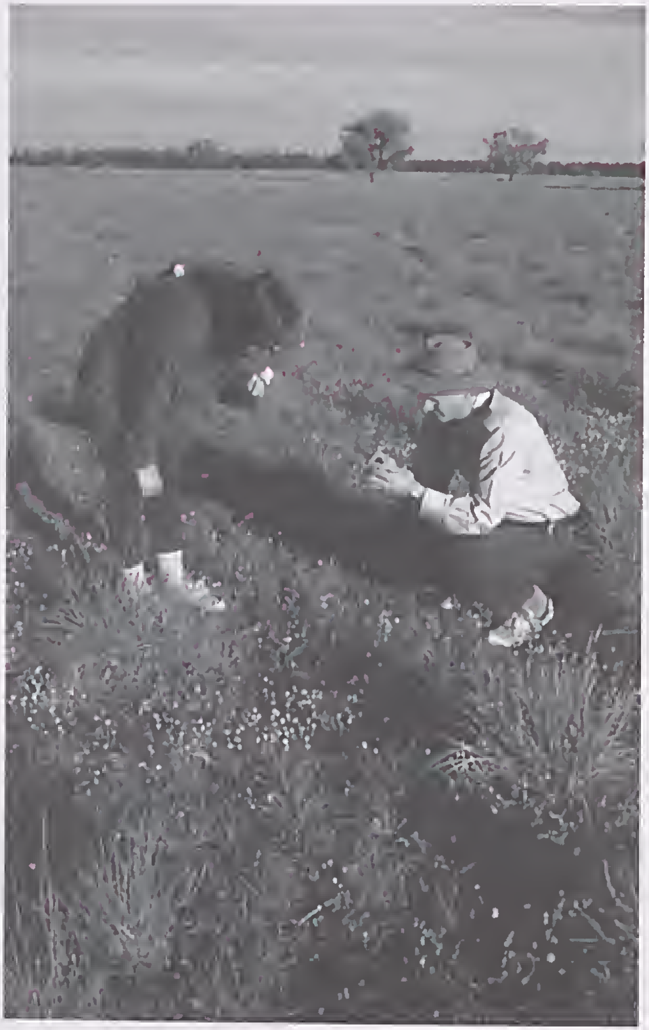

Fig 14. SWG 1 in Community 1a on 'Morundah' with *Lomandra effusa* and *Leptorhynchos squamatus* subsp. A in the foreground with scattered *Acacia pendula* in the background. Photo: M. Porteners.

Table 4. Structure and vegetation community of Plains-wanderer sites.

Site	**Plains-wanderer habitat type (from Maher 1996)**	**Layer**	**Structure October 1995 Hgt (m)**	**% Cover**	**Comm**
SWG 1	suitable Mar/Apr 1995	tussock	0.3	25	1a
		herb/grass	0.1	60	
SWG 8	suitable Mar/Apr 1995	tussock	0.3	35	3
		herb/grass	0.1	60	
SWG 9	suitable Mar/Apr 1995	tussock	0.5	40	3
		herb/grass	0.1	40	
SWG 10	marginal Mar 1995	tussock	0.4	35	4
		herb/grass	0.1	60	
SWG 13	suitable Mar 1995	herb/grass	0.2	90	1a
SWG 15	P-w recorded 1982–1995	herb/grass	0.2	70	1b
SWG 16	suitable Dec 1993	herb/grass	0.3	70	1b
SWG 21	suitable Oct 1995, o/grazed Mar/Apr 1995	herb/grass	0.2	60	1a
SWG 25	suitable Mar 1995	tussock	0.3	50	1a
		herb/grass	0.2	25	
		herb/grass	0.1	10	
SWG 26	suitable Mar 1995	tussock	0.3	40	1a
		herb/grass	0.25	30	
		herb/grass	0.1	15	
SWG 28	suitable Mar/Apr 1995	tussock	0.5	10	1a
		herb/grass	0.1	60	
SWG 29	suitable Mar/Apr 1995	shrub	0.3	15	1a
		herb/grass	0.1	50	
SWG 30	suitable Mar/Apr 1995	herb/grass	0.2	70	1a
SWG 42	suitable Mar/Apr 1995	tussock	0.5	30	1a
		herb/grass	0.1	40	
SWG 49	P-w recorded 1982–1995	tussock	0.4	40	4
		herb/grass	0.1	40	
SWG 52	P-w recorded 1982–1995	tussock	0.3	50	1b
		herb/grass	0.1	20	
SWG 53	P-w recorded 1982–1995	tussock	0.3	50	1b
		herb/grass	0.1	30	
SWG 59	marginal Apr 1995	tussock	0.3	60	1a
		herb/grass	0.1	30	
SWG 60	marginal Dec 1993	tussock	0.3	35	1a
		herb/grass	0.1	20	
SWG 63	o/grazed Mar/Apr 1995	tussock	0.3	50	3
		herb/grass	0.1	30	
SWG 64	suitable Mar/Apr 1995	tussock	0.3	30	1a
		herb/grass	0.1	20	

defined by Maher (1996), and their structure and vegetation community as defined in this study.

Discussion

The analysis of the site data suggests there are four main types of native grassland in the region: Communities 1a and 1b combined cover most of the southern and eastern areas; Community 3 occupies lower lying sites in eastern areas with higher nutrient soils; Community 4 is restricted to the western part of the region on grey cracking soils; and Community 5 occurs in poorly drained sites or 'swamps'. Community 2 should be considered as a regrowth woodland with a native grassland ground cover. It is possible that other sites (such as site 1 at 'Morundah') contained woodland patches as remnant *Callitris* trees are present nearby.

The main environmental determinants of species and grassland community distribution are soil type, rainfall and hydrology. All grasslands occur on clay soils but these differ in the texture and nutrients across the landscape depending on their depositional origin, distance from river channels and erosional status. Scalding was commonly observed in Communities 1a and 1b.

Compared to other temperate grassland regions of Australia (McDougall & Kirkpatrick 1994), the derived native grasslands of the Riverine Plain are extensive. Significant plant species and species-rich grasslands survive in restricted patches that are less disturbed—the best native grassland sites were found in areas that had not been ploughed. Additionally, the occurrence of rare species such as *Swainsona plagiotropis*, *Sclerolaena napiformis* and *Brachycome papillosa* mainly on travelling stock routes and road reserves suggests that these areas have not been continuously heavily grazed or cultivated. Continuous grazing adversely effects some flora. Moore (1953a) recorded the Native Yam, *Microseris lanceolata*, in 24% of his sites, but it was recorded only once during our survey. Upright forbs such as this are more susceptible to stock grazing compared to flat-rosette species (McIntyre et al. 1993). *Microseris lanceolata* would appear now to be threatened in the region.

The survey also revealed that some species previously regarded as rare are not so. *Swainsona murrayana* is listed nationally as a threatened species, yet it occurred in one third of the sites sampled. It is not a rare species in the region but may be rare in other parts of its range. Similarly, the yellow daisy *Brachycome chrysoglossa* was located in half of the Community 1a sites and so is relatively common, but it is considered to be vulnerable in Victoria. Alternatively, the single recording of the first confirmed specimen in NSW of *Leptorhynchos scaber*, along with the nationally endangered *Lepidium monoplocoides* on the 'Morundah' site confirms their threatened ranking in the region.

For some species rarity cannot be adequately assessed from one survey as they are ephemeral or respond differently to rainfall patterns or disturbances such as fire. 1991 was a bumper year for *Swainsona plagiotropis* relative to recent years. This may have been a response to the high rainfall of 1991 as well as to the fire that swept through Jerilderie at that time.

Seasonal or annual changes in the vegetation

The relative abundance of species and the structure of a patch of grasslands differs from year to year depending on the timing and level of rainfall, temperatures and degree of grazing by stock. This is illustrated by Figs 15 and 16 showing the Council-owned paddock on the western fringe of Jerilderie in October 1995 and October 1991. In October 1995 the site was dominated by Cape Weed (*Arctotheca calendula*), without a tall cover of grassland. The paddock had been heavily stocked and may also have been recovering from drought. The same site in October 1991, before the onset of the drought and during a spring of high rainfall, contained tall *Danthonia* grasses and little Cape Weed. On both occasions, however, inspection revealed that the species composition was similar, including the presence of the vulnerable *Swainsona plagiotropis*. What had changed was the degree of dominance of certain species and the growth stage (structure) of the grassland. This example highlights the danger of judging the condition of a grassland on one visit only.

In their report on the locations of *Swainsona plagiotropis* Chappell & Luke (1994) noted the species from 22 locations, many of which adjoin each other. We sampled three of these locations at SWG 7, 22, and 38 but failed to record this species. This illustrates the ephemeral nature of some species in the region and reveals that longer term monitoring is required to establish an understanding of the flora.

Plains-wanderer habitat

The fact that Plains-wanderers have always been found in the Riverina raises a question about habitat requirements and the pre-European vegetation structure. Baker-Gabb's evidence (1990) shows that the birds have very specific and narrow habitat requirements and, in particular, are intolerant of upper canopy and dense grassland. However, Moore (1953a and 1953b) and others indicate that prior to European settlement, the Riverina was principally a shrubland community of *Acacia pendula* and *Atriplex* species. For these facts to remain consistent, the original shrubland vegetation must have been patchy, with the birds occupying the open areas of sparse grassland in between. The sparse grassland was probably restricted to soils that were scalded by wind erosion—much as it is today.

Although 70% of the Plains-wanderer sites measured in this survey were in Community 1, this would be expected as that community is the dominant one in the area: 61% of all vegetation sample sites were in Community 1. Also, 63% of vegetation sites of Community 1 had no related Plains-wanderer records. Consequently, the vegetation community type or floristic composition are not necessarily good predictors of Plains-wanderer habitat. If grassland structure is the key determinant of Plains-wanderer habitat, it changes rapidly over time and single measurments will not reveal the suitability of a site for the bird.

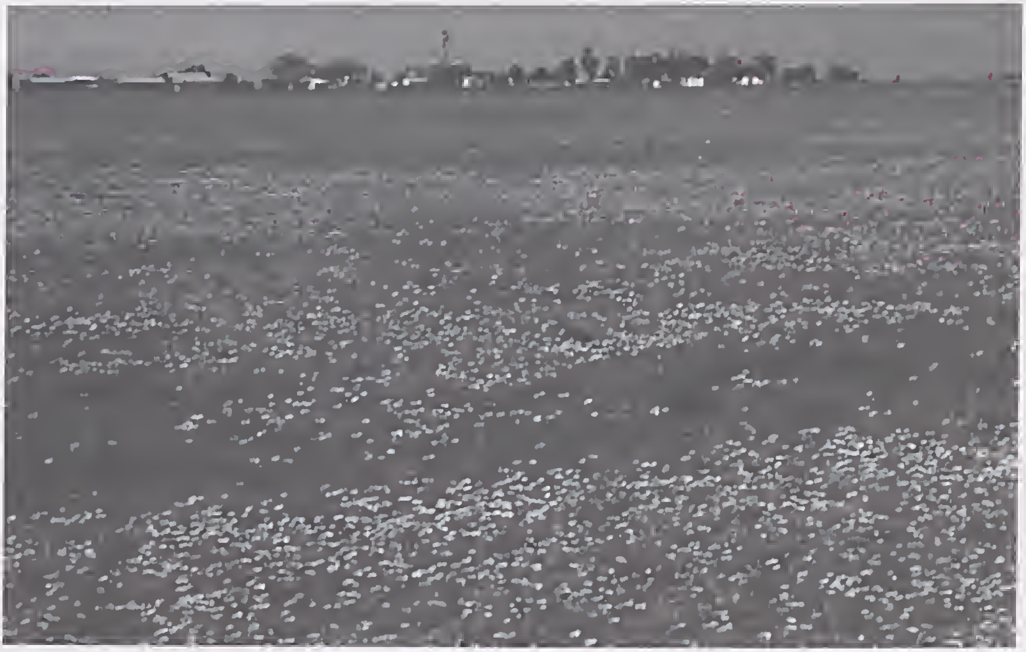

Fig. 15. Paddock on the western side of Jerilderie owned by Jerilderie Shire Council photographed in October 1995. Cape Weed *(Arctotheca calendula)* was abundant and the native grasses were very short. Photo: M. Porteners.

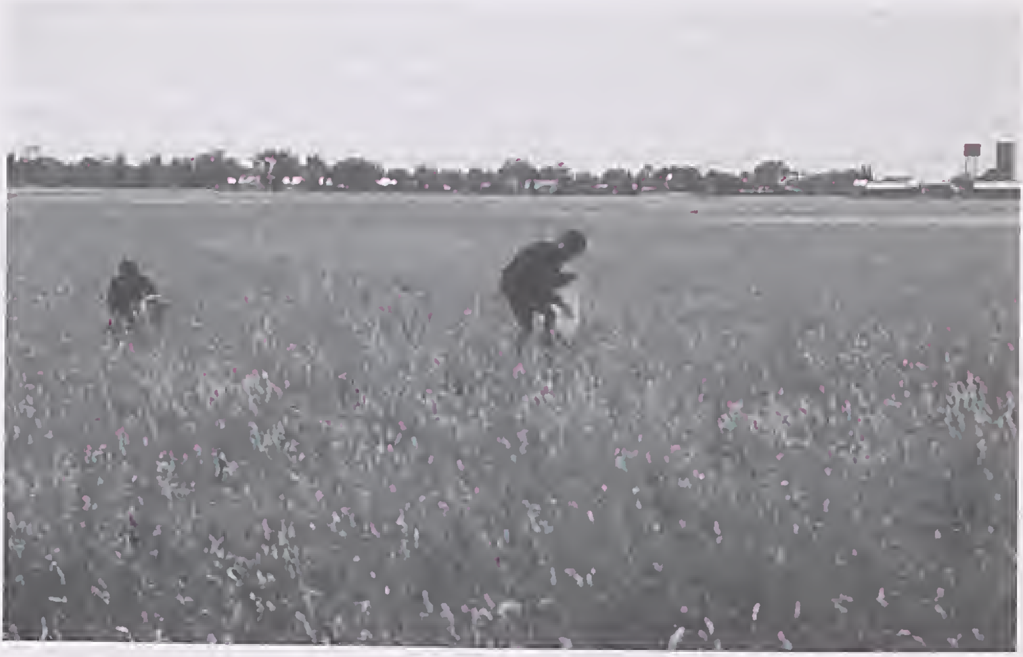

Fig 16. The same Council-owned paddock shown in Figure 15 but in October 1991. Cape Weed is not abundant and tall native grasses dominate the grassland. Photo: J. Benson

Threats to and management of native grasslands

The greatest threat to the native grasslands on the Riverine Plain is further extension of cultivation for either pasture improvement or crops. With the expansion of markets in Asia for Australian rice, there is a demand for increased production of this crop. Rice farming is intensive agriculture requiring major earthworks to build paddy fields (Fig. 17), applications of fertiliser and pesticides, and the use of large quantities of water. It is extending beyond the floodplains of the major rivers to areas relying on bore water for irrigation. It is possible that its expansion could conflict with grassland conservation. Site inspection to ascertain the importance of an area should be mandatory before any rice paddies are constructed in native grasslands in the region.

Ploughing of paddocks for any reason (including the sowing of exotic pastures) may threaten important sites for native grassland protection. Most properties have some areas of improved pasture. A balance needs to be struck between the maintenance of native grasslands and exotic grasslands. Ploughing provides an environment suitable for the invasion of exotic weeds. Even in the 'best' native grasslands, exotic species made up a significant proportion of the flora.

There is increased salinisation in the Riverina due to a rising saline water table caused by increased irrigation and the clearing of deep-rooted perennial vegetation (Macumber 1990). This problem, and its economic impacts on the Murray-Darling Basin as a whole, is discussed by Crabb (1988). Its impact on the various ecosystems on the Riverine Plain is likely to increase in the future. This may be a major long term threat to all vegetation including native grasslands. Since many of the native grasses

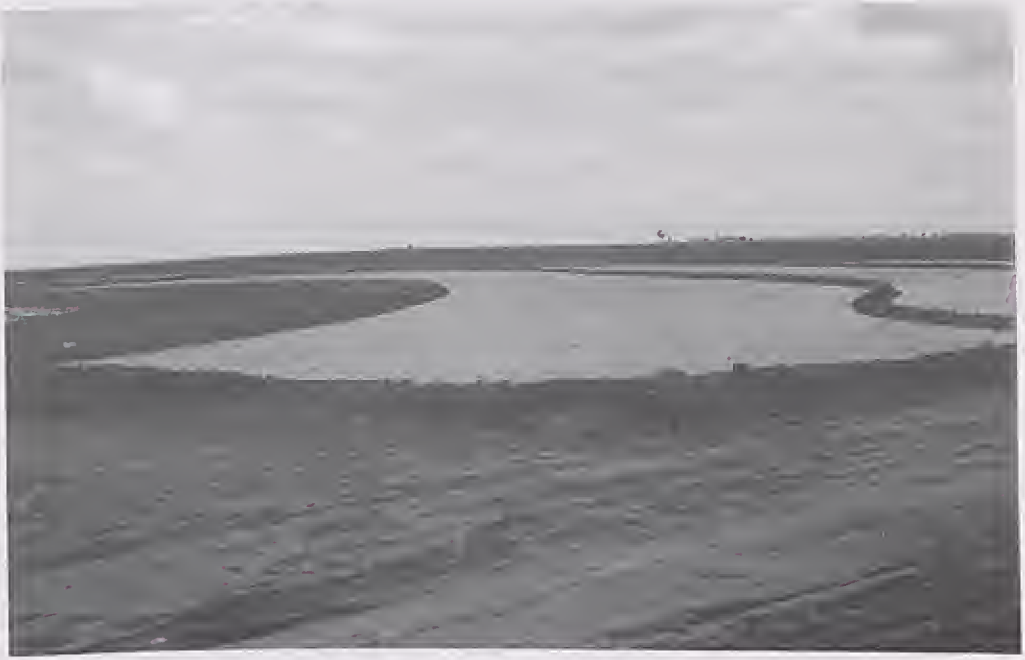

Fig. 17. One of the major threats to native grasslands on the Riverine plain is the construction of additional rice paddy fields where the grassland is completely destroyed. Photo: John Benson

are biannual or short-lived perennial (Leigh & Mulham 1966) and deep-rooted, their maintenance may help minimise future salinisation.

Over-grazing remains a threat to native grasslands. Continuous and often heavy grazing by stock over the last 150 years has markedly reduced the cover of chenopod shrubs, palatable native perennial grasses and native annual forbs in favour of exotic annual species (Cheal 1993). Some plant species have only survived in areas that have been lightly or not continuously grazed. Stock grazing should be excluded from areas where it has been absent in the past (Lunt 1991). Such areas are rare on the Riverine Plain but may include fenced-off roadsides or paddocks such as site SWG 3. Certain regimes of grazing may benefit some native grasslands and retain a diverse range of native species. Inter-tussock forbs, in particular, may be out-competed by vigorous grass growth (Tremont 1994) if biomass is not reduced. This can be achieved through either light grazing or infrequent burning. Large properties such as 'Coonong', 'Boonoke' and 'Cocketgedong' are generally not over-stocking their native grasslands. Diez & Foreman (1996) recommend that past grazing regimes should continue, or be lowered in intensity, at sites which contain valuable native grassland. They also suggest that stock should be removed, or their numbers lowered, in important sites between August and November, when most native species of grass and forbs flower and set seed. Heavy grazing in the flowering and fruiting season may influence the soil seed bank and hence future abundance of some native species. Examples where this could apply are where the threatened plants *Swainsona plagiotropis* and *Brachycome papillosa* survive on travelling stock reserves and adjoining paddocks around Jerilderie. These areas have been grazed, but in a way that has not eliminated these species—probably intermittently. Important sites should not be grazed during wet periods where pugging by stock can severely disturb the soil.

The rabbit population in the native grasslands of the Riverine Plain is limited by the prevalence of clayey soils that inhibit burrowing. This contrasts with the impact of rabbits on vegetation on loamy and sandy ridges such as on 'Zara' and 'Oolanbeyan', or elsewhere, for example, Yathong Nature Reserve to the north of the region (Leigh et al. 1989).

Fire is known to be important in maintaining species diversity in some native grassland types such as those dominated by *Themeda australis* (Stuwe & Parsons 1977). On the Riverine Plain fire is infrequent compared to eastern regions and its impacts are largely unstudied. Nevertheless, some plant species may benefit from burning due to its impact on biomass and its role in stimulating some seeds to germinate. The intensity and frequency of fire cannot be recommended without research and it is likely to be different for particular communities or species.

The indiscriminate use of herbicides kills native grasses and forbs, although selective use can be important for controlling exotic weeds. Application of fertilisers mainly favours exotic annual species over most of the native grassland species (Lunt 1991). Another occasional threat to native grasslands is the inappropriate planting of trees in landscapes where they did not originally grow. This is often done by well-meaning community groups or local government. On the Riverine Plain it would be quite appropriate to grow Myall (*Acacia pendula*) on the cracking clays where it was once common, but not appropriate to plant other tree species that never occurred in this habitat.

Several sites on the edge of Jerilderie are threatened by expansion of the town. Planning for the town's growth should take into account the presence of these sites. The significant grassland owned by the Australian Navy at 'Morundah' (SWG 1) could be adversely affected by the postion of a communications tower and associated frequent burning, mowing and road construction. Impacts would be minimised if the tower was placed distant from the paddock containing the significant grassland.

Conservation of native grasslands

Sites of botanical significance are summarised in Table 3 and detailed descriptions of these sites are given in Benson et al. (1996). Most of the native grassland in the region is being managed for extensive grazing. In some cases this can be compatible with native grassland conservation. Conflict arises where native grasslands are ploughed, over-fertilised or over-grazed.

The Western Riverina Grassland Management Plan should be reviewed regularly to take new information into account. This Plan should stipulate clearly how native grassland will be protected and managed in the region. Given that the majority of the region is used for grazing domestic stock, minimal stocking rates should be encouraged (Diez & Foreman 1996).

Many of the more important sites containing threatened plant species are on public lands—road reserves and travelling stock reserves. There is an opportunity for the managers of such sites to enter into conservation agreements under the NSW National Parks and Wildlife Act to formalise sympathetic management of their native grasslands. Several areas warrant nature reserve status so that these ecosystems are sampled in the State's reserve system. These TSRs and/or nature reserves would be suitable places for long term research on species and native grassland management.

Future research

This survey provided a basis of understanding the different types of native grasslands and their species composition on the Riverine Plain. It may be beneficial for managing the different native grasslands communities if they could be mapped. Some could be more easily mapped than others. Community 4 is restricted to the western section of the study area; Community 3 is restricted to the centre and eastern parts; Community 5 is restricted to swamps. The greatest difficulty in a native grassland mapping exercise would be to distinguish between Communities 1a, 1b, 3 and exotic pastures, as these are widespread and overlap in their distribution. Mapping the native grassland communities would best be achieved through intensive field work, working from property to property at a reasonably fine scale of resolution. It would be beneficial for such a project to be conducted in spring after good rainfall, as this may lead to the discovery of additional species and sites of botanical significance, thereby assisting the development of plans for grassland conservation. In contrast, summer fieldwork can target native perennial grasses with less abundance of annual species.

Long term monitoring of species changes in relation to climatic and disturbance factors at some key sites such as 'Morundah', the Council-owned paddock at Jerilderie, the travelling stock reserves and on 'Coonong' would assist in managing these sites. Demographic studies of threatened species, such as that outlined in Foreman (1994) for *Swainsona plagiotropis* would underpin the management of key species.

Our results reveal that further work on linking botanical data to Plains-wanderer habitat is required, particularly in relation to the structure of the grassland and grazing management. The absence of Plains-wanderers at one point of time does not necessarily mean they will not be present in the future because the structure of grasslands changes, with the seasons, grazing intensity and other disturbances. Also, since little is known of the reptiles, mammals and invertebrates that live in the native grasslands of the region, surveys of these would help refine conservation priorities.

A native grassland conservation program will only succeed with the involvement of the local community. This has already commenced as a consequence of the compilation of the Western Riverina Grassland Management Plan by the Murrumbidgee Catchment Management Committee, but more needs to be done. A primary objective should be the development of a detailed regional native grassland management plan linked to property management plans, both of which should be based on sound biological survey, research results and community knowledge.

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Appendix 1: Detailed locations of 67 sampling sites in the study area, showing AMG grid references and 1:100 000 map sheets. The map sheets are Buraja 8126 (Bur), Coleambally 8028 (Col), Conargo 7927 (Con), Gunbar 7929 (Gun), Hay 7828 (Hay), Jerilderie 8027 (Jer), Lockhart 8227 (Loc), Moggumbill 7928 (Mog), Urana 8127 (Ura), Wanganella 7827 (Wan), and Yanco 8128 (Yan). Sites in known Plains-wanderer habitat (Maher 1996) are marked with an asterisk.

Site	East	North	Map	Location Description
*SWG 1	446100	6122900	Ura	'Morundah'
SWG 2	408300	6095800	Jer	Urana Rd, 3.6 km E Colombo Ck Bridge
SWG 3	421800	6093300	Ura	1km W Lake Urana, Pn 29, Ph 'Cocketgedong'
SWG 4	414500	6095100	Ura	9.4 km E Colombo Ck Bridge, W Urana
SWG 5	451600	6091100	Ura	'Invermay'
SWG 6	429800	6056200	Bur	7 km W Daysdale
SWG 7	386300	6085600	Jer	1 km E Jerilderie, on Oaklands Rd
*SWG 8	429000	6106300	Ura	5 km NW along Coonong Siding from Morundah Rd
*SWG 9	415000	6108900	Ura	'Coonong'
*SWG 10	364000	6111300	Jer	Moonbria Lane, 6.5 km W Wilson Rd, opposite 'Eastpark
SWG 11	369500	6122600	Jer	Mabins Well Rd, 0.7 km from Mabins Corner Tank
SWG 12	369500	6122600	Jer	McLennons Bore Rd, 7.1 km from Jerrys Lane
*SWG 13	402400	6114200	Jer	Airstrip on Bundure Rd
SWG 14	376700	6088200	Jer	Hynes Lane, 9 km W Jerilderie
*SWG 15	340600	6104500	Con	Black Sandhill Paddock on 'Boonoke', 2.3 km NW ruins
*SWG 16	357600	6155500	Mog	1.2 km E along 'Cooinbil' access road
SWG 17	360400	6206300	Gun	Carrathool Rd, 23.5 km S Tabbita Lane
SWG 18	343500	6193200	Gun	'Uardry' outstation road, 8.0 km N Carrathool-Hay Rd
SWG 19	413700	6094500	Ura	1 km NE 'Cocketgedong' between homestead and Urana Rd
SWG 20	419000	6093800	Ura	Urana-Jerilderie Rd, 4 km W Lake Urana
*SWG 21	410500	6099600	Ura	'Cocketgedong', 2 km S Colombo Ck
SWG 22	383300	6085300	Jer	Near Jerilderie airstrip, E Newell Hwy
SWG 23	380200	6077900	Jer	Newell Highway, 8 km SW Jerilderie
SWG 24	376700	6084900	Jer	Intersection Hynes Lane and South Coree Rd
*SWG 25	387400	6091300	Jer	1 km SE 'Willawa' woolshed
*SWG 26	385900	6091800	Jer	2 km S 'Willawa' woolshed
SWG 27	399300	6094200	Jer	1 km W 'North Yathong'
*SWG 28	413100	6108200	Ura	'Coonong'
*SWG 29	427200	6104700	Ura	'Coonong', 2 km SW Coonong Rd
*SWG 30	429100	6107400	Ura	'Coonong', Pn 70
SWG 31	444300	6089500	Ura	Between Urangeline Ck and Lockhart-Urana Rd

SWG 32	411900	6088400	Ura	On S side Nowranie Ck, near Nowranie
SWG 33	369800	6104500	Jer	'Wononga', Pn 106 on Crockett's Lane
SWG 34	370000	6110000	Jer	Moonbria Rd, 800 m from Wilson Rd
SWG 35	379500	6114600	Jer	Jerry's Lane, 9.8 km from Coleambally Rd
SWG 36	367000	6149900	Col	2 km SE 'Cooinbil' homestead
SWG 37	371900	6145300	Col	0.5 km NW 'Cooinbil' woolshed on homestead road
SWG 38	305900	6089900	Jer	0.5 km W Innes Bridge on Elliott Lane
SWG 39	421400	6111300	Ura	Coonong Siding Road, 5 km SE from Newell Highway
SWG 40	433500	6107200	Ura	Narrandera-Urana Rd, 3.6 km N Coonong Siding Road
SWG 41	437800	6123600	Ura	7 km N along Narrandera-Urana Rd
*SWG 42	445200	6125300	Ura	'Morundah', Pn 58
SWG 43	446000	6122500	Ura	Swamp on 'Morundah'
SWG 44	344800	6088600	Con	Conargo-Jerilderie Rd, 10 km E Conargo
SWG 45	355900	6085400	Con	Intersection Coree Rd and Conargo-Jerilderie Rd
SWG 46	353900	6088400	Con	'Heartwood', Pn 37, 1 km NW homestead
SWG 47	307400	6120500	Wan	Warwillah Rd
SWG 48	307100	6080800	Wan	Near Boree Ck escape channel, 2 km N 'Pretty Pine'
*SWG 49	329300	6104600	Con	Willurah Rd on 'Boonoke', 8 km N Conargo
SWG 50	327900	6115600	Con	Willurah Rd, 5.7 km N Delta Ck
SWG 51	330000	6138500	Mog	1 km W Conargo-Burrabogie Rd, 2 km N Coleambally Ck
*SWG 52	343300	6109500	Con	'Boonoke', 5.5 km S Edgar State Forest
*SWG 53	337400	6105300	Con	'Boonoke', Pn 63, Charlies Paddock
SWG 54	313500	6070800	Wan	Cobb Highway, 4.6 km NW Deniliquin
SWG 55	296300	6083600	Wan	Moulamein Rd, 13 km NW 'Pretty Pine'
SWG 56	288900	6112100	Wan	14 km W along Wanganella-Moulamein Rd on'Windrington'
SWG 57	301300	6170300	Hay	Jerilderie Rd, 0.6 km W Cobb Highway, 9 km S Hay
SWG 58	314400	6163300	Hay	Intersection Glencoe Rd and Jerilderie Rd
*SWG 59	359400	6109800	Con	Moonbria Rd, 3 km S 'Moonbria' homestead
*SWG 60	355500	6142400	Mog	Carrathool Rd, at Four Corners Tank
SWG 61	358100	6167500	Mog	Gum Ck on Gum Ck Rd
SWG 62	333100	6168000	Mog	Burrabogie Lane, 12 km S Sturt Highway
*SWG 63	412300	6117500	Ura	1 km N Yellow Clay Ck
*SWG 64	419100	6123800	Ura	1 km W Muddy Ck
SWG 65	418900	6139700	Yan	Yamba Rd, 0.5 km N Morundah Rd
SWG 66	456500	6112700	Loc	John's Rd, 2 km west of Oaklands-The Rock railway
SWG 67	499800	6112800	Loc	Bullenbong Plain, eastern edge

Appendix 2. Plant species list, their percent occurrence in sites per community and overall. Species recorded from outside the sample plots are indicated by X; species recorded by Chappell and Luke (1994) are marked 'A'. Nationally rare or threatened species are marked 'ROTAP'; rare or threatened taxa in Victoria 'Vic'; extension of known range within NSW 'Ext'; new record for NSW 'New'. Introduced species are marked with an asterisk.

	% Occurrence in Community (number of sites)						
Botanical Name	**1a (24)**	**1b (17)**	**2 (1)**	**3 (7)**	**4 (15)**	**5 (3)**	**Overall (67)**
Amaranthaceae							
Alternanthera denticulata	21	6		14		67	12
Ptilotus exaltatus var. *exaltatus*	67	24	100	43			36
Ptilotus polystachyus var. *polystachyus*^{Vic}	X		100				1
Ptilotus spathulatus	13	6		14			7
Amaryllidaceae							
Calostemma purpureum	8		X		7	33	6
Anthericaceae							
Arthropodium minus	13			43			9
Dichopogon fimbriatus	8	12	100	29			10
Thysanotus patersonii			100				1
Apiaceae							
Daucus glochidiatus form G	79	88	100		27		58
Eryngium plantagineum	4	X		29			4
Eryngium rostratum	17	6		14			9
Asphodeliaceae							
Bulbine bulbosa	42	6	100	43			22
Bulbine semibarbata		12			33	33	12
Asteraceae							
Actinobole uliginosum	4		100				3
**Arctotheca calendula*	75	71	100	86	73	67	75
Brachycome basaltica var. *gracilis*	X						
Brachycome chrysoglossa$^{Vic, New}$	46						16
Brachycome lineariloba	4	6					3
Brachycome muelleroides $^{ROTAP, Vic}$						33	1
Brachycome papillosa $^{ROTAP, A}$							
Brachycome species B					7		1
Calocephalus citreus	13	6		29			9
Calocephalus sonderi	58	59		14	33		45

Calotis anthemoides	4			43			6
Calotis cuneata var. *cuneata*	4						1
Calotis hispidula	17		100		7		9
Calotis scabiosifolia var. *scabiosifolia*	46	82		43	33	33	51
**Carthamus lanatus*	8						3
Chrysocephalum apiculatum	92	76	100	43			58
**Cirsium vulgare*	13	6		14	13		10
**Cotula bipinnata*	63	71		29	53	67	58
Eclipta platyglossa				14		33	3
Euchiton sphaericus	4	6			7		4
**Hedypnois rhagadioloides* subsp. *cretica*	33	41		29	20		30
Hyalosperma glutinosum subsp. *glutinosum*	71	12	100	43	27		40
Hyalosperma semisterile		6	100				3
**Hypochaeris glabra*	96	59	100	100	27		52
Isoetopsis graminifolia	63	35					31
Leptorhynchos elongatus^{Vic}					20		4
Leptorhynchos panaetioides^{Vic}	21	71		29	40		37
Leptorhynchos scaber^{New}						X	
Leptorhynchos squamatus subsp. A	39	6		43			19
Leucochrysum molle^{Vic}	13	47					16
Microseris lanceolata	X						
Minuria leptophylla			100				1
Myriocephalus rhizocephalus	63	6		43		67	31
Myriocephalus stuartii				14			1
**Onopordum acaulon*	4						1
Podolepis jaceoides^{A}							
Podolepis muelleri					7		1
**Podospermum resedifolium*	4	6		14			4
Pogonolepis muelleriana	4						1
Pycnosorus globosus	8	12		14	7	100	13
Rhodanthe corymbiflora	92	100		57	100	33	88
Rhodanthe pygmaeum	33	18	100		13		21
Senecio runcinifolius		6					1
**Sonchus asper* subsp. *glaucescens*	13	6		14	20		12
**Sonchus oleraceus*	13	12					7
Stuartina muelleri	4		X				1

**Taraxacum officinale*						33	1
Triptilodiscus pygmaeus	96	24	100	14			43
Vittadinia cervicularis var. *subcervicularis*	4			X			1
Vittadinia cuneata var. *cuneata*	4	6			20		7
Vittadinia cuneata var. *hirsuta*	17	18	100				12
Vittadinia gracilis	X				7		1
Vittadinia pterochaeta^{Vic}	4				7		3
Boraginaceae							
Cynoglossum suaveolens			100				1
**Echium plantagineum*	25	47		57	67		42
Brassicaceae							
Lepidium monoplocoides^{ROTAP,Vic,Ext}						X	
**Rapistrum rugosum*	4	6					3
**Sisymbrium orientale*		6					1
Campanulaceae							
Wahlenbergia gracilenta	4	12		14			3
Wahlenbergia gracilis	46	6					19
Wahlenbergia luteola	4		100				3
Wahlenbergia stricta subsp. *alterna*	4	X	100				4
Caryophyllaceae							
**Spergularia rubra*	21				27		18
Casuarinaceae							
Allocasuarina verticillata			100				1
Centrolepidaceae							
Centrolepis glabra						33	1
Chenopodiaceae							
Atriplex leptocarpa	8	35		29	67		30
Chenopodium desertorum subsp. *virosum*	8	18					7
Enchylaena tomentosa		6			7		3
Maireana aphylla^{Vic}	25	35		29	47		31
Maireana decalvans^{A}							
Maireana excavata^{Vic}	79	53			47		52
Maireana pentagona	96	94		57	47		75
Rhagodia spinescens		6	X				1
**Salsola kali*	13	35		14	13		18
Sclerolaena diacantha	4						1

Sclerolaena muricata var. *semiglabra*	8	X			20		7
Sclerolaena muricata var. *villosa*	4	12		14	27		12
Sclerolaena napiformis^{ROTAP,Vic}		X					
Sclerolaena stelligera	X	12		14	27		10
Colchicaceae							
Wurmbea dioica subsp. *dioica*	79	41	100	71	7	33	51
Convolvulaceae							
Convolvulus erubescens	33	X	100	14	7		16
Dichondra species A				14			1
Crassulaceae							
Crassula colorata var. *acuminata*	54	29		29	73		46
Crassula decumbens var. *decumbens*	46	6		71	13	67	31
Cupressaceae							
Callitris glaucophylla^{Vic}			100				1
Cyperaceae							
Eleocharis pallens^{Vic}	X			14		67	4
Isolepis congrua^{Vic}	X			14			1
Isolepis hookeriana						33	1
Isolepis victoriensis						33	1
Droseraceae							
Drosera glanduligera			100				1
Euphorbiaceae							
Chamaesyce drummondii	33	47			33		31
Fabaceae–Faboideae							
**Medicago polymorpha*	17	18		14	47		22
**Medicago praecox*		6					1
**Medicago truncatula*	67	88		57	87	33	73
Swainsona behriana^{Ext}	33	18	100	X			18
Swainsona murrayana^{ROTAP,Vic}	46	29		29		33	28
Swainsona plagiotropis^{ROTAP,Vic}	4			14			3
Swainsona procumbens	21	12		29		100	18
Swainsona sericea^{A}							
Swainsona swainsonioides^{Vic}		X			X		
**Trifolium angustifolium*	4	6					3
**Trifolium arvense*	38	24	100	86	13		33
**Trifolium campestre*				14			1

**Trifolium glomeratum*	25			43			13
**Trifolium hirtum*	4						1
**Trifolium repens*				29		33	4
**Trifolium subterraneum*	4			14			3
**Trifolium tomentosum*	4	6		29	7		7
Fabaceae - Mimosoideae							
Acacia homalophylla^{A}							
Acacia pendula^{Vic}	X	6			X	X	1
Gentianaceae							
**Cicendia quadrangularis*	X						
Geraniaceae							
**Erodium cicutarium*	21	12			53		22
Erodium crinitum	17	29	100	29	40		27
**Erodium malacoides*	X						
Goodeniaceae							
Goodenia fascicularis	79	65		57	33		58
Goodenia pinnatifida	13	6	100		7		9
Goodenia pusilliflora	67	53	100	29	33		49
Haloragaceae							
Myriophyllum crispatum						67	3
Hypoxidaceae							
Hypoxis glabella var. *glabella*	21	18		28	7		16
Iridaceae							
**Gynandriris setifolia*	21	18					12
**Romulea minutiflora*	29	12	100		13		18
**Romulea rosea*	50	53		71	13		42
Juncaceae							
Juncus aridicola				14		33	3
**Juncus articulatus*						67	3
**Juncus bufonius*	4			14			3
Juncus radula	17			29		67	12
Juncaginaceae							
Triglochin procerum						33	1
Lamiaceae							
**Marrubium vulgare*		6					1
Teucrium racemosum	17	41		14	13	67	24

Lentibulariaceae							
Utricularia dichotoma						33	1
Linaceae							
Linum marginale	17			14	7		9
Lobeliaceae							
Pratia concolor				14			1
Lomandraceae							
Lomandra effusa	4		100				3
Lythraceae							
**Lythrum hyssopifolia*	4					33	3
Malvaceae							
Sida corrugata	88	88		29	73	33	75
Sida trichopoda		6					1
Marsileaceae							
Marsilea drummondii						100	4
Myoporaceae							
Eremophila longifolia			100				1
Nitrariaceae							
Nitraria billardierei	X	X					
Ophioglossaceae							
Ophioglossum lusitanicum subsp. *coriaceum*^{A}							
Orchidaceae							
Diuris dendrobioides s. lat.^{Ext}			X				
Diuris lanceolata^{Ext}			X				
Prasophyllum campestre			100				1
Oxalidaceae							
Oxalis perennans	58	35	100	57	47		48
Phormiaceae							
Dianella longifolia var. *porracea*			X				
Plantaginaceae							
**Plantago coronopus* subsp. *commutata*	13						4
Plantago cunninghamii	13	12		14	7		10
Plantago drummondii	4	29			7		10
Plantago gaudichaudii	4						1
Plantago hispida	4			14			3
Plantago turrifera	13	12			7		9

Poaceae

Agrostis avenacea var. *avenacea*	8	12			7	100	12
**Aira elegantissima*	17		100				7
**Alopecurus geniculatus*	13	6		29		67	12
Amphibromus macrorhinus	X			14			1
Aristida jerichoensis var. *jerichoensis*			100				1
**Avena fatua*	42	59	100	43	87		55
**Briza minor*	17			43		33	12
**Bromus diandrus*	X						
**Bromus molliformis*	13				7		6
Chloris truncata	92	71		43	20	33	61
Chloris ventricosa^{A}							
Danthonia caespitosa	50	29		14		33	33
Danthonia duttoniana		18			7	67	9
Danthonia eriantha	33	6	100	14	27		22
Danthonia laevis				14			1
Danthonia linkii var. *fulva*	4	12		14	33		13
Danthonia linkii var. *linkii*	4	18		29	7		10
Danthonia setacea	4	18		14	7		9
Enteropogon ramosus	25	41		57	73		42
Eragrostis australasica					X	67	3
**Eragrostis cilianensis*					X		
Eulalia aurea				14			1
**Holcus lanatus*		6		14			3
Homopholis proluta	25	24		86	40	67	36
**Hordeum leporinum*	17	12		14	40	33	21
**Lolium rigidum*	88	100		86	93	67	90
Monachather paradoxa			X				
**Pentaschistis airoides*	4					33	3
**Phalaris aquatica*				14	27		7
**Rostraria cristata*	17	6					7
Sporobolus caroli^{Vic}	8	29			7		12
Stipa aristiglumis	4	6		71		33	12
Stipa bigeniculata	13	X		14			6
Stipa eremophila			100				1
Stipa nodosa	92	88		14	73		73

Stipa setacea^{Vic}			X	14			1
Themeda australis			100				1
Thyridolepis mitchelliana			100				1
**Vulpia bromoides*				14	7		3
**Vulpia muralis*	17	6		14	7		10
**Vulpia myuros*	4	12			20		9
Polygonaceae							
Rumex dumosus		6		43			6
Rumex tenax				14		33	3
Portulacaceae							
Calandrinia eremaea	4						1
Primulaceae							
**Anagallis arvensis*				14			1
Proteaceae							
Hakea tephrosperma^{Vic}			100				1
Ranunculaceae							
Myosurus minimus var. *australis*		X				33	1
Ranunculus pachycarpus	4						1
Ranunculus pentandrus var. *platycarpus*		6		43	7	67	10
Ranunculus pumilio var. *politus*				14			1
Ranunculus sessiliflorus var. *pilulifer*	4						1
Rosaceae							
Aphanes australiana	X			14			1
Rubiaceae							
Asperula conferta	50	29		86	7		36
Scrophulariaceae							
**Parentucellia latifolia*	29		100	43			16
**Veronica peregrina*						33	1
Sinopteridaceae							
Cheilanthes sieberi subsp. *sieberi*	4		100				3
Solanaceae							
Solanum esuriale	17	18			7		12
Stackhousiaceae							
Stackhousia monogyna			100				1

Stylidiaceae				
Levenhookia dubia	100			1
Stylidium despectum			33	1
Thymelaeaceae				
Pimelea micrantha	100			1
Zygophyllaceae				
Zygophyllum glaucum		7		1

Native and naturalised shrubs of the Bathurst Granites: past and present

W.S. Semple

Semple, W.S. (Department of Land and Water Conservation, PO Box 53, Orange 2800) 1997. Native and Naturalised shrubs of the Bathurst Granites: past and present. Cunninghamia *5(1): 49–80.* The Bathurst Granites (Kanimbla Batholith) occupy a large area to the west of the Blue Mountains in New South Wales. Trees and shrubs are infrequent but are relatively common on rocky granite hills and surrounding non-granite hills. Historical material suggests that shrubs were also infrequent at the time of European settlement in the early 1800s. A search of the literature on the flora of the Bathurst Granites and a roadside survey of the western part, resulted in a list of 107 taxa of shrubs and low trees. Diversity of native shrubs was generally higher on hilly sites, granite or non-granite. Exotic species comprised about 20% of the total granite shrub flora. Landscapes with a long history of disturbance, e.g. more fertile areas, had a higher proportion of exotics. There is some evidence that the relatively low numbers and diversity of native shrubs on granite landscapes, compared to surrounding areas of similar topography, may apply to granite areas elsewhere. It is suggested that the abundance of native shrubs is related to the absence of a continuous sward of perennial grasses, which is, in turn, related to soil fertility.

Introduction

West of the Blue Mountains plateau is an extensive area of granite, which extends from the vicinity of Katoomba to west of Bathurst (Fig. 1). Apart from rocky hills such as Evans Crown (1104 m ASL), most of the area has sparse tree cover. This contrasts sharply with surrounding areas, which are underlain by metamorphic and sedimentary rocks, and commonly have moderate to dense tree cover (Fig. 2). This contrast was observed at the turn of the century by Clunies Ross (1898) and was probably evident at the time of European settlement.

The most obvious trees on many parts of the granite are exotics - particularly willows, poplars and pines. Belts of pine (mainly *Pinus radiata*) were planted here, as in other areas subject to cold, windy and/or wet winters (e.g. the basalt plains of western Victoria), as shelter for stock. In recent times however, a range of other tree values, including enhanced pasture/crop growth and control of some forms of land degradation, has been recognised (e.g. see review by Bird et al. 1992). Added to this is a renewed appreciation in the rural community of native vegetation and its role as habitat for native fauna, including those which may be predators of insect pests (e.g. Davidson 1995).

Largely due to the opportunities provided by the Landcare movement, trees are again being planted on a large scale. Shelter belts commonly consist of native rather than exotic species as was the practice in the past. However, to provide effective shelter, narrow belts of eucalypts require a shrub understorey. Further, there is evidence

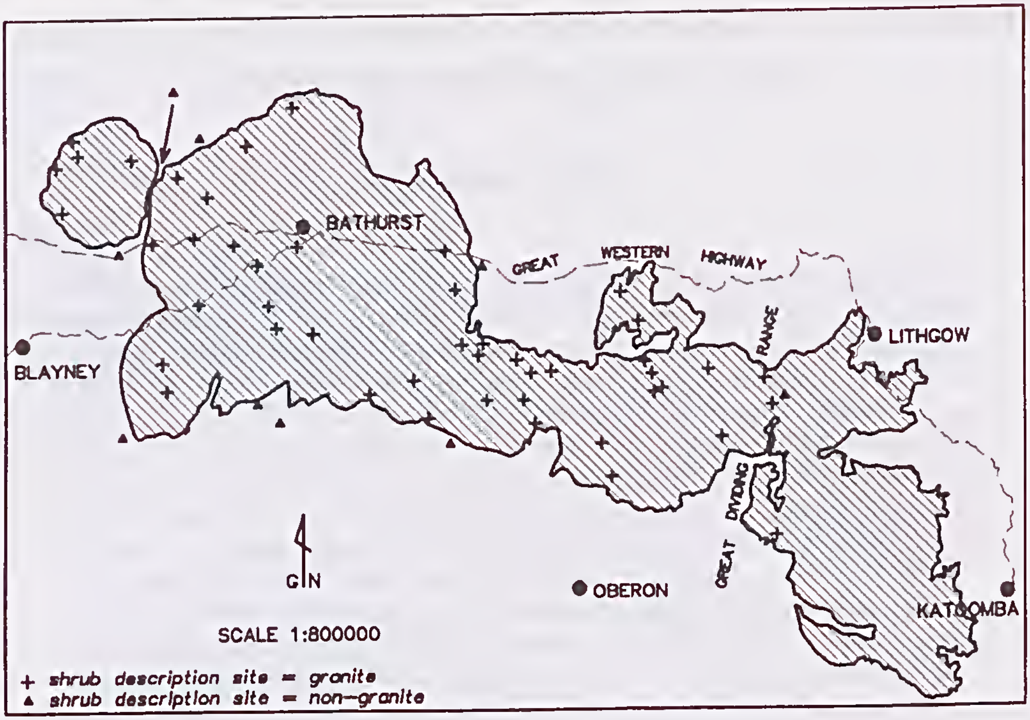

Fig 1. The extent of the Bathurst Granites. Adapted from Bryan (1966) and Packham (1968).

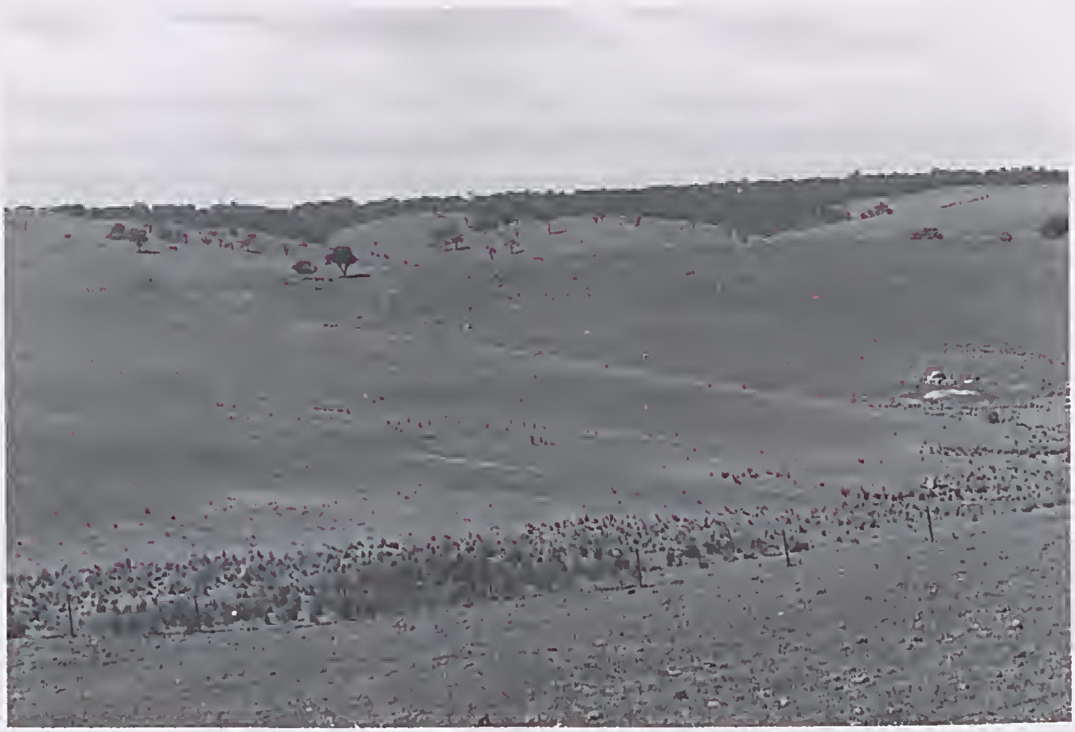

Fig 2. Metamorphosed sediments with timber cover (background) are in sharp contrast to the almost treeless granite country. South of Wimbledon.

(P.R. Bird, pers. comm.) that the presence of shrubs enhances the growth and survival of young eucalypts.

A number of native (e.g. *Acacia*) and exotic (e.g. *Cotoneaster* and *Pyracantha*) shrub species are suitable for the granite soils of the Bathurst area but the choice of native species is limited due to lack of published information; though vegetation surveys such as that of Keith & Benson (1988) will address this if extended to more westerly areas. This lack of information not only affects choice of shrub species for on-farm plantings, but also limits attempts at 'recreating' original landscapes as occurs, to some extent, in rehabilitating roadsides (e.g. Wakefield 1994) or creating well-prepared wildlife corridors (e.g. Wilson & Lindenmeyer 1996).

In an attempt to add to the knowledge of the shrub flora of the granite soils of the Bathurst area, a search of the literature and field survey were carried out during 1992-95. The aims of the project were to:

1. Compile a list of native and naturalised shurbs occurring in the area,

2. Prepare, from (1), a list of native species, which were potentially useful for the shrub component of on-farm tree plantings, and

3. Relate the occurrence of shrubs to particular substrates, including adjacent non-granite areas and to discuss changes which may have occurred since European settlement of the area in the early 1800s.

The primary aim of the project was (2), which was requested by the Bathurst office of the Soil Conservation Service. The list was prepared as an unpublished report in 1995.

Physical environment of the Bathurst Granites

The 'Bathurst (or Kanimbla) Batholith' was formed by intrusion of acid magma into Ordivician, Silurian and Devonian sediments during the Carboniferous. Recent geological mapping by Wyborn and Pogson (1994) has divided the area into a suite of granites: Bathurst, Dunkeld, Eusdah, etc., which are collectively referred to here as the 'Bathurst Granites'. Uplift associated with the intrusion created a region of net erosion which still continues. The surrounding sediments, including the metamorphic aureole, were generally more resistant to erosion than the granite, resulting in a rim of elevated country around much of the exposed batholith (Somerville 1987). West of the Great Dividing Range (1100–1200 m ASL), where caps of Permian sediments overly the granite, the overall effect is a basin centred on Bathurst. The lowest point (620 m) is where the Macquarie River exits the exposed batholith.

The area is located within the Central Tablelands botanic subdivision of New South Wales. The relatively high altitude and its range are reflected by the climate. Median annual precipitation ranges from about 1000 mm on the Great Dividing Range to 750 mm west of Bathurst and is lowest (c.600 mm) in the Bathurst Basin. Occasional snowfalls occur throughout much of the area—particularly above 1000 m ASL. Although temperatures fall by about 6.4°C per 1000 m in summer and by 3.7°C per 1000 m in winter, cold air drainage can reverse this effect resulting in increased

Table 1. **Relative fertility attributes of the main soils of and adjacent to the Bathurst Granites—west of the Great Dividing Range (Adapted from Kovac et al.1990)**

	Soils occurring on granite					Adjacent non-granite soil			
Main soils	Siliceous sands, sandy earth, podzols	Yellow solodics	Red solodics	Non-calcic brown soils	Prairie soils	Yellow podzolics	Red podzolics	Yellow soloths	Shallow soils
Soil landscapes	Pine Mt. Rocks Evans Plains	Raglan lower slopes of: Rocks Bathurst	Raglan	Bathurst	Macquarie Evans Plains	Lambie Mayfield	Mookerawa Mullion Ck. Mayfield	lower slopes of: Mookerawa Mullion Ck	Lambie
Fertility attributes:									
Drainage	well	poor	moderate	well	moderate	imperfect	moderate to well	imperfect	well
Water-holding capacity	low	high	high	moderate	high	low to moderate	low to moderate	high	low
Depth to bedrock (cm)	100+	300+	250	170	200+	60 to 150+	105 to200	150+	30
Topsoil pH	6.0	6.5	6.0 to 7.5	6.0	7.0	4.0 to 6.0	5.5 to 7.5	5.0 to 7.0	4.0
Chemical fertility	low	low	low	moderate	high	low	low to *moderate*	low	low

frequencies of fog and frost in low-lying areas (Bowie 1987). At Bathurst, for example, about 20 frosts per month occur in July and August (Anon. 1974).

Reconnaissance soil mapping west of the Great Dividing Range by Kovac et al. (1990) divided the erosional surfaces of the granite into four soil landscapes: 'Pine Mountain' and 'Rocks'—lands of high elevation and relief with siliceous sands and podzolic soils, 'Bathurst'—undulating lands with non-calcic brown soils and yellow solodics, 'Raglan'—slightly undulating plains with red and yellow solodics. Similar country to the 'Rocks' was subdivided into three landscapes in more detailed soil mapping to the east by King (1993, 1994). Alluvial landscapes include 'Macquarie' and 'Evans Plains', where siliceous sands, prairie soils, earthy loams, black earths and wiesenboden occur. The relative fertilities of the main soils are presented in Table 1.

Relationships between relief, climate, soils and presumed original vegetation in the Central West of NSW (which includes most of the Bathurst Granites) have been summarised by Bowie (Goldney & Bowie 1987, Fig. 2, p.7).

Vegetation of the Bathurst Granites during the settlement period: evidence for the occurrence and frequency of shrubby plants

The main sources of evidence for the nature of the original vegetation are from accounts of early visitors and from so-called 'remnant stands' of vegetation. Both sources are considered but with emphasis on the historical.

Amongst the many problems in interpreting the work of early visitors (who were mainly interested in vegetation from the points of view of access, timber and/or grazing value) is the changing meaning of words; 'forest' being a particular example:

> *FOREST ... 1. A large space of ground or wood-land, left uncultivated; or partly pasture, and partly wood, for breeding and hunting beasts of chase, etc. 2. [In law] a certain territory of woody grounds and fruitful pastures, privileged for wild beasts and fowls of forest, chace and warren, to rest and abide in, the safe protection of the king for his pleasure ...*
>
> (Bailey 1764).
>
> *... Forest land is such as abounds with Grass and is the only Ground which is fit to Graze; according to the local distinction the Grass is the discriminating Character and not the Trees for by making use of the Former it is clearly understood as different from a Brush or Scrub ...*
>
> (Governor King writing to Earl Camden, 1 Nov. 1805; cited by Ryan et al., undated)
>
> *Forest ... a wild uncultivated tract of ground with wood ...*
>
> (Fulton & Knight 1831).

Clearly, the 'forest' of the writings of the early to mid 1800s is not 'forest' as is presently understood. It could, however, encompass lands which have dense trees; but it does not completely agree (as is implied by Ryan et al. 1996) with our present understanding of a 'woodland'.

'Plains' too was used differently in the 1800s. According to Rolls (1981, p. 42)

> *... the colonists called any treeless area plains provided they were not steeply hilly ...*

Extracts from the early literature which follow are selective in the sense that some reference to the presence and absence of shrubs was sought. It is hoped that they are not misleading, a criticism levelled by Croft et al. (1996) at Ryan et al.'s (undated) compendium of extracts from historical sources.

Early descriptions of the landscapes of the Bathurst Granites

The first Europeans to view the granite landscapes were G. Blaxland, G. Lawson and W. Wentworth, who crossed the Blue Mountains plateau in mid-1813. The western extremity of their exploration was a 900 m hill (later named Mt Blaxland) at the eastern end of the Bathurst Granites.

Following the explorers' return to Sydney, Governor Macquarie instructed Assistant Surveyor, G. Evans, to explore the new country. With five others, he departed in November 1813, crossed the Great Divide, named the 'Bathurst Plains' and followed the Macquarie River (also named by him) almost to its junction with the Turon River. In July 1814, W. Cox, T. Hobby, R. Lewis and a gang of convicts began constructing a road from Emu Plains to Bathurst. It was completed in February 1815 and two months later, Macquarie and entourage travelled to Bathurst and proclaimed the settlement on 7 May 1815 (Barker 1992).

Other early visitors to the area included Cunningham and Oxley (1817), Darwin (1836) and considerably later, Maiden and Cambage (c.1909) retracing Cunningham's journey. These early visitors left written records of their journeys though their descriptions are often difficult to reconcile with the present landscape. All, however, noted the contrast between the sandstones of the Blue Mountains and the land below the escarpment where small areas of Permian sediments, as well as granite, occur (Bryan 1966). Examples include:

G. Blaxland 1813:

> *... On the 28th* [May 1813]*... they took up their station on the edge of a precipice* [Mt York]. *To their great satisfaction, they discovered that what they had supposed to be sandy barren land below the mountain was forest land, covered with good grass, and with timber of an inferior quality ...*[the next day] *... They reached the foot at nine o'clock, AM., and proceeded two miles, north-north-west, mostly through open meadow land, clear of trees, the grass from two to three feet high ...*
>
> (Blaxland 1823, reprinted in Richards 1979, pp. 73–74).

Describing the area between Mt York and the Cox's River in the early 1900s, Maiden & Cambage reported that it was a:

> *... well defined botanical boundary, for we have hitherto been traversing the sandstone with its showy flora; we now (at Cox's River) get on to the granite with its larger trees (except in the sandstone gullies), and very much sparser flora. Let Allan Cunningham speak* [from his unpublished 1817 journal]: *... Here was observed the very remarkable change of country,*

> *differing from that on the mountains both in the vegetable production and nature of soil the* Banksia serrata *ceases to exist further westerly than the summit of Mount York, and …* B. marginata *succeeds, throughout the Vale (Clwydd) …*
>
> (Maiden & Cambage 1909, p. 129).

Darwin 1836:

> *… Soon after leaving Blackheath, we descended from the sandstone platform by the pass of Mount Victoria … We now entered upon a country less elevated by nearly a thousand feet, and consisting of granite. With the change of rock, the vegetation improved; the trees were both finer and stood farther apart; and the pasture between them was a little greener and more plentiful …*
>
> (Darwin 1968 reprint, p. 440).

Very few of the early accounts of the granite country itself refer to dense timber though clearly this existed, e.g. Lewin's 1815 painting of Evans Crown (Fig. 3A) and Antill's 1815 description of the same area:

> *… We appeared to be completely surrounded and hemmed in by a range of hills. The country from Cox's River abounds with red and black granite; … and the whole aspect of the country appeared as if it had undergone some great convulsion of nature, hills heaped upon hills and rocks upon rocks, with deep gullies between them, and all clothed with wood to their very summits …*
>
> (Antill 1965 reprint, p. 7).

Evans' account from the Great Dividing Range near the present Cheetham Trig. (1131 m ASL) (Weatherburn 1966) in November 1813 is somewhat ambiguous with respect to shrub and tree density:

> *… I came to a very high mount where I was much pleased with the sight westward. I think I can see 40 miles which had the look of an open country. To the south and north there are large hills, much higher than the one I am on, with pasture to their tops. The range is rather over run with underwood and larger timber growing thereon, but the sides are as green as possible …*
>
> (Evans 1813 in Walker's 1913 facsimile).

In another of the few references which note the presence of a shrubby understorey, W. Cox, the road builder, in describing the Fish River country south of Evans Crown noted:

> *… The land got hilly, and falls more into gullies than lower down. It is also shrubby in places and more timber on it …*
>
> (Cox's 1814–15 journal in Anon. 1979, p. 110).

A year earlier, G. Evans referred to the Fish River—possibly in the same area as:

> *… I now find the mimosa in clusters on the banks of the river. The country continues good particularly for grazing. Yet it has not been altogether so pleasing to the eye as before, being in some places over run with a shrub among the grass, somewhat the same as on the Cow*

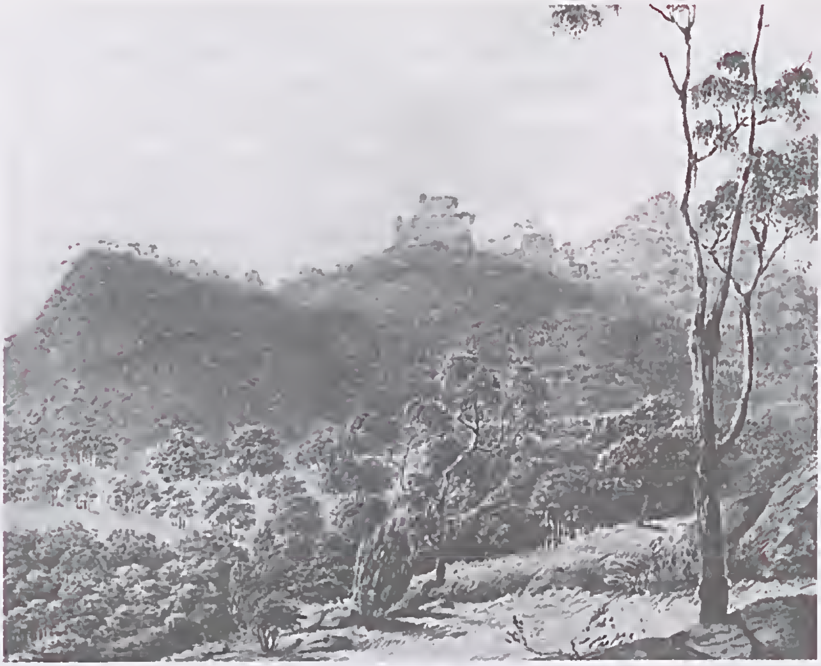

Fig 3A. Evans Crown as depicted by J.W. Lewin in 1815 (Breckwoldt (1988) presents a coloured reproduction of this scene together with an 1815 view of the 'Bathurst Plains').

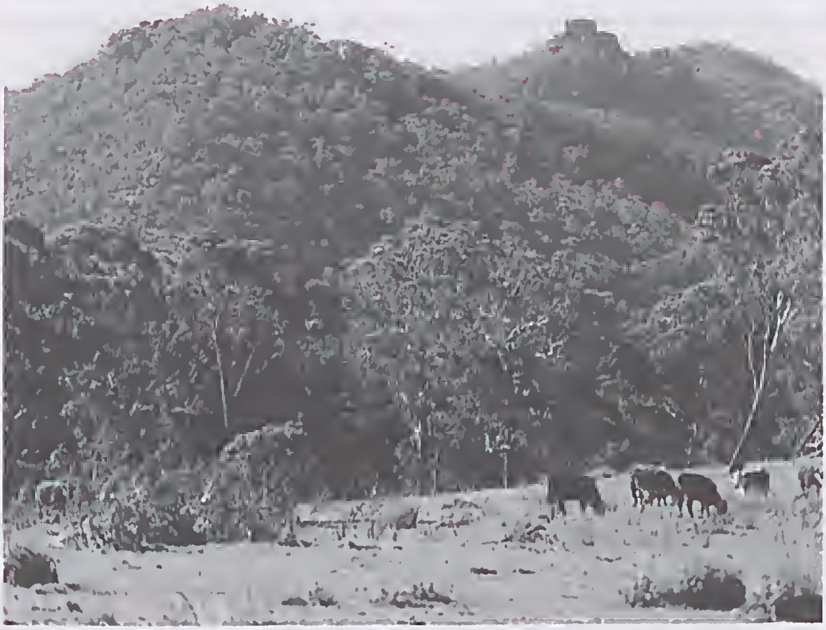

Fig 3B. Evans Crown from near Mt. Olive in 1996.

> *Pastures near Stone Quarry Creek. The land is still of a light sandy nature, thinly wooded with small gums …*
>
> (Evans 1813 in Walker's 1913 facsimile).

Perhaps the best known of the early descriptions of the Bathurst area are extracts from Governor Macquarie's journal of his first visit in 1815. For example:

> *… After riding about 9 miles* [from the Campbell River crossing] *through a pretty wooded country we arrived on a height which commanded a very extensive, grand, and noble view of the Bathurst Plains extending on both sides of the Macquarie River for 11 miles and for nearly 3 miles on each side of it, being almost entirely clear of timber for that extent …*
>
> (Macquarie 1956, p. 97).

The country in the vicinity of Bathurst was clearly lightly timbered:

> *… Within a distance of ten miles from the site of Bathurst, there is not less than 50,000 acres of land clear of timber, and fully one half of that may be considered excellent soil, well calculated for cultivation. It is a matter of regret, that, in proportion as the soil improves, the timber degenerates; and it is to be remarked, that every where to the westward of the Mountains, it is much inferior both in size and quality to that within the present colony; there is, however, a sufficiency of timber of tolerable quality , within the district around Bathurst, for the purpose of housebuilding and husbandry …*
>
> (Government and General Orders 10 June 1815, reprinted in Richards 1979, p.127).

As it turned out, there was insufficient timber for fuel in the early period of settlement (Templeton 1976) and, no doubt, the removal of what timber there was had a significant effect on the early landscape.

From these descriptions, it seems that Macquarie was describing alluvial plains such as the 'Macquarie' and 'Evans Plains' soil landscapes. However, Darwin's 1836 description clearly indicates that the treeless country also extended to non level country—probably the 'Raglan' soil landscape east of Bathurst:

> *… In the afternoon we came in view of the downs of Bathurst. These undulating but nearly smooth plains are very remarkable in this country, from being absolutely destitute of trees …* (Darwin 1968 reprint, p. 442).

Many of the early descriptions refer to lightly timbered country; e.g. Blaxland's 1813 report from Mt. Blaxland:

> *… In the afternoon, they ascended the summit, from whence they descried all around, forest or grassland, sufficient in extent, in their opinion, to support the stock of the Colony for the next thirty years …*
>
> (Blaxland 1823, reprinted in Richards 1979, p. 75).

It is likely that the early visitors tended to highlight the lightly timbered country because of its perceived value for grazing and farming. Also, the route of Cox's Road (see maps in Maiden & Cambage 1909 and Carey 1976), by which the early visitors travelled, would have followed the open country wherever possible. Writing from the vicinity of this road in May 1815 Antill noted:

> *... We proceeded up the bank of the Campbell River for about three miles, upon the banks of which we were to encamp near a bridge made over it ... the face of the country we rode over this day after quitting the road, was beautiful and open, large tracts of land without timber or underwood, and in the spring when grass is green must be delightful ...*
>
> (Antill 1965 reprint, pp. 8–9).

The Campbell River crossing at that time is shown as a woodland in one of Lewin's 1815 paintings (Fig. 4). Another scene (Sidmouth Valley, Fig. 5A) shows an alluvial flat with grassland, lower slopes with woodland and hills with woodland and/or forest; the scene today (Fig. 5B) is similar to that depicted in 1815.

Evidence from the present vegetation

Before considering the present vegetation, it is pertinent to note some of the major events that have occurred since settlement. Some examples from Barker (1992):

- decline in numbers of aboriginals and an increase in the numbers of Europeans — particularly since the discovery of gold in the district in the 1850s
- introduction of domestic livestock in 1815
- construction of roads, e.g. Cox's in 1815 and Mitchell's in the 1830s, and the railway in the 1860s and 70s

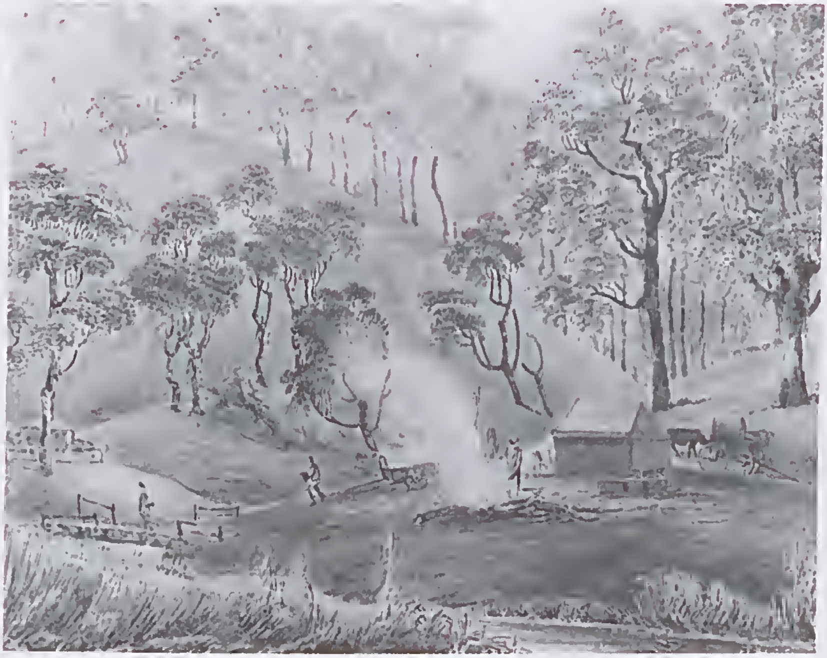

Fig 4. Governor Macquarie's camp at the Campbell River crossing as depicted by J.W. Lewin in 1815.

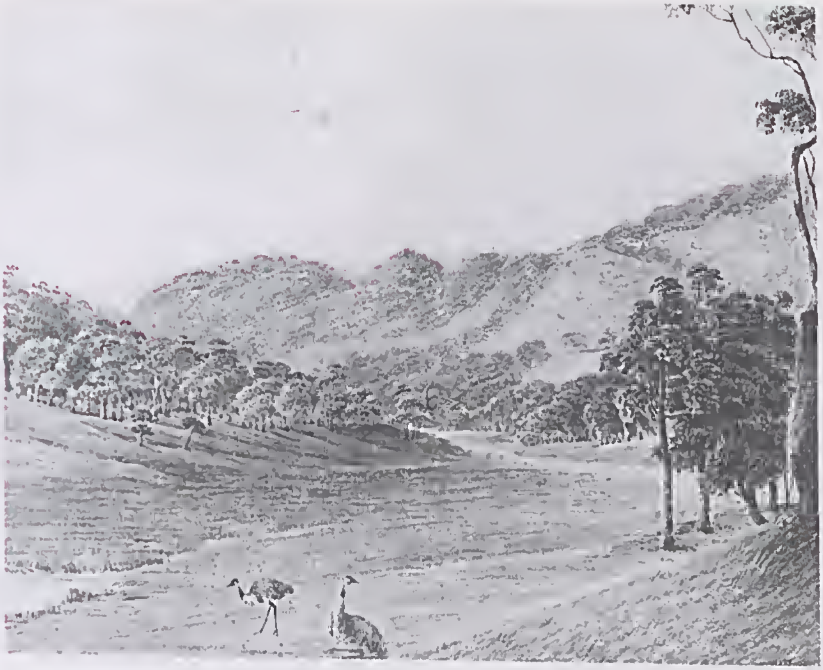

Fig 5A. Sidmouth Valley from the vicinity of Cox's Road as depicted by J.W. Lewin in 1815.

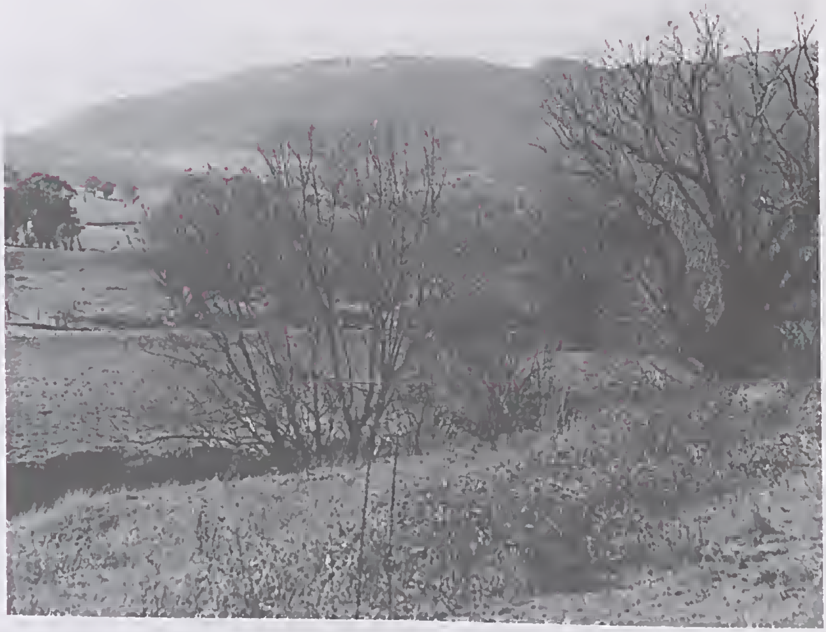

Fig 5B. The same scene from the Carlwood Road (presumed to closely follow Cox's Road) at Black Soil Flat in 1996. The trees in the mid ground are willows, introduced since Lewin's time.

- arrival of rabbits in the late 1850s (Stacy 1976) and other exotics such as blackberry
- introduction of subterranean clover and superphosphate for 'pasture improvement' in the 1950s (Smith, undated). This was apparently partly responsible for the reduction in the area of sheet erosion recorded between 1943 and 1967 (Anon 1974)

Cultivation was initially restricted to the treeless flats. In one such area, the Fitzgerald Valley, south-west of Bathurst, chaff, hay, wheat, maize, cream and pigs were being produced by the late 1880s (Smith, undated). The commencement of large-scale clearing of timber from the Bathurst Granites is unknown though Smith (undated, p. 17) reported that

> *... when the clearing of the undulating country ... began in earnest about the early 1930s it was found to be suited to the growing of wheat and oats. This country was described in 1899 as being rough and hilly ...*

Also uncertain is the time of formation of the large gullies for which the Bathurst district is well-known (Semple et al. 1995). The gullies are still active (Crouch & Blong 1989) and are common sites of invasion by exotic shrubs such as blackberries (*Rubus* spp.), Sweet Briar (*Rosa rubiginosa*) and African Boxthorn (*Lycium ferocissimum*) (Fig. 6).

What interpretation can be made from existing stands of timber such as occurs on Evans Crown? The vegetation is not dissimilar to that sketched in 1815 (Figs. 3A and 3B). It could be argued that the structure of the vegetation is much as it was, though the understorey, at least, would have been affected by the introduction of other plants and animals, reduced fire frequency, etc.

In the case of small areas of timber in apparently cleared paddocks (e.g. Fig. 7), the interpretation is less clear. Are they remnants of the original vegetation and if so, are they representative of adjacent areas that appear to have been cleared? As areas are left uncleared for a reason (e.g. too rocky, poorly drained, potential use as timber, or for stock shelter), it is unlikely that they can be considered representative of the surrounding areas. In some cases the supposed 'remnants' appear to be denser than originally described, e.g. the country below Mt York (Fig. 8). It is unlikely that Blaxland (cited earlier) would have described it as he did, if the area was completely covered with timber as dense as in the 'remnants'.

A further explanation of the apparent discrepancy between early and current descriptions of the vegetation is that considerable woody plant regeneration may have occurred following settlement. This has been reported from other areas, e.g. Gippsland (Howitt cited by Anderson 1941), the semi-arid woodlands of western NSW (e.g. Anon. 1969), the Pilliga area (Rolls 1981) and the Gulgong area (Nicholson & Seis 1993). A possible explanation for this is that lignotuberous eucalypt seedlings were present in the original woodlands but suppressed by grass competition and regular burning. Following increased grazing by domestic stock and the reduced frequency of fires this growth, previously un-noticed, would have been released. According to Florence (1996), this mechanism was probably responsible for the rapid regrowth of forests following logging in the early days of settlement.

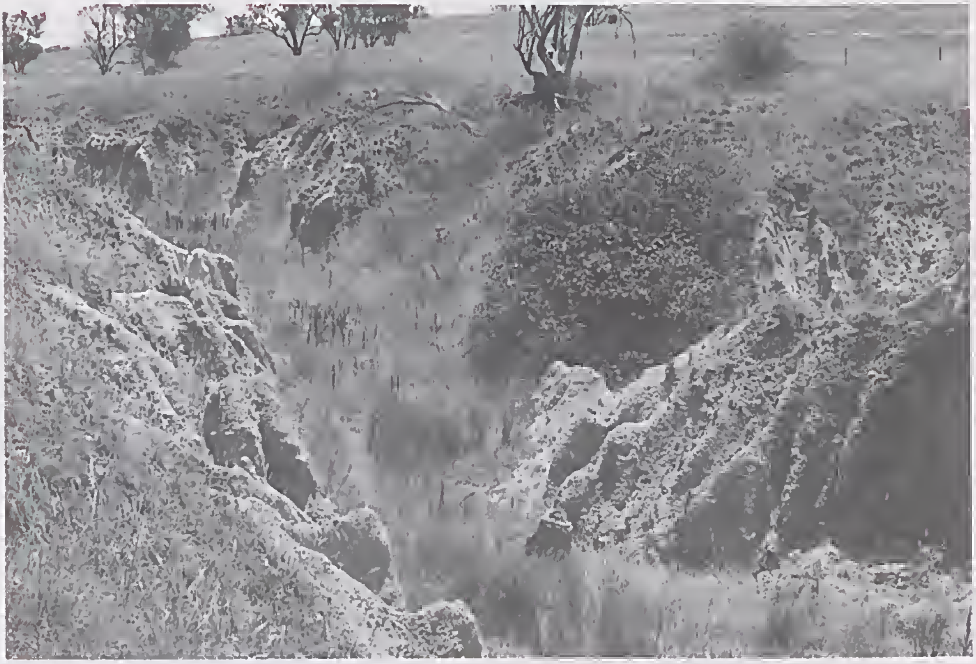

Fig 6. Erosion gullies are common sites of exotic shrub invasion.

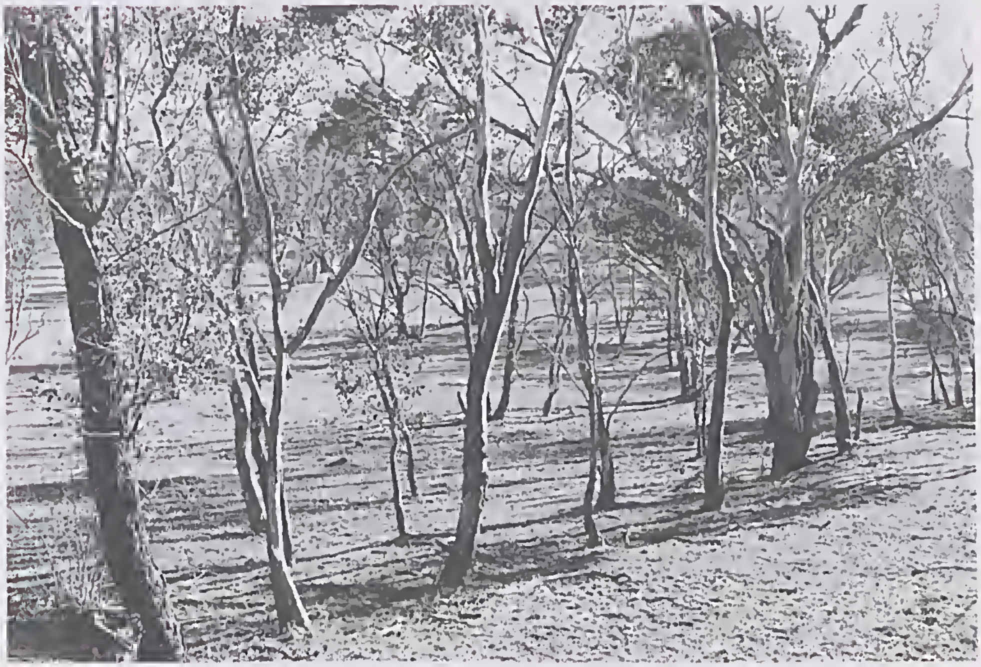

Fig 7. A *Eucalyptus melliodora–E. blakelyi* woodland south-east of Bathurst. It is uncertain (though unlikely) that this is representative of the original vegetation.

A survey of shrubs occurring on the Bathurst Granites

The primary aim of the survey described below was to compile a list of shrubs that may be suitable for the understorey of on-farm tree plantations. As a consequence, a somewhat broader view of 'shrub' than that used by Harden (1990–93) was adopted. Low non-eucalypt trees, which commonly branch near ground level, e.g. many *Acacia* spp., were included. Though naturalised* shrubs and those <2 m mature height were considered unsuitable for habitat/shelter plantations, opportunity was taken to record them in the survey.

The literature, including compilations of species lists by Pickard (1972), Bryant & Benson (1981), Keith (1988) and Benson & Melrose (1993), was searched for previous records of shrubs. Accounts of the vegetation by Chisholm (1923), Cambage (1902) were of little use due to the lack of distinction between granite and non-granite substrates. The main sources were Maiden & Cambage (1909), National Parks and Wildlife Service (undated), Wakefield (1994) and Clunies Ross (1898).

The latter was particularly useful as a clear distinction between the granite and non-granite flora was made. However, Harden's (1990–1993) *Flora* and Jacobs & Pickard's

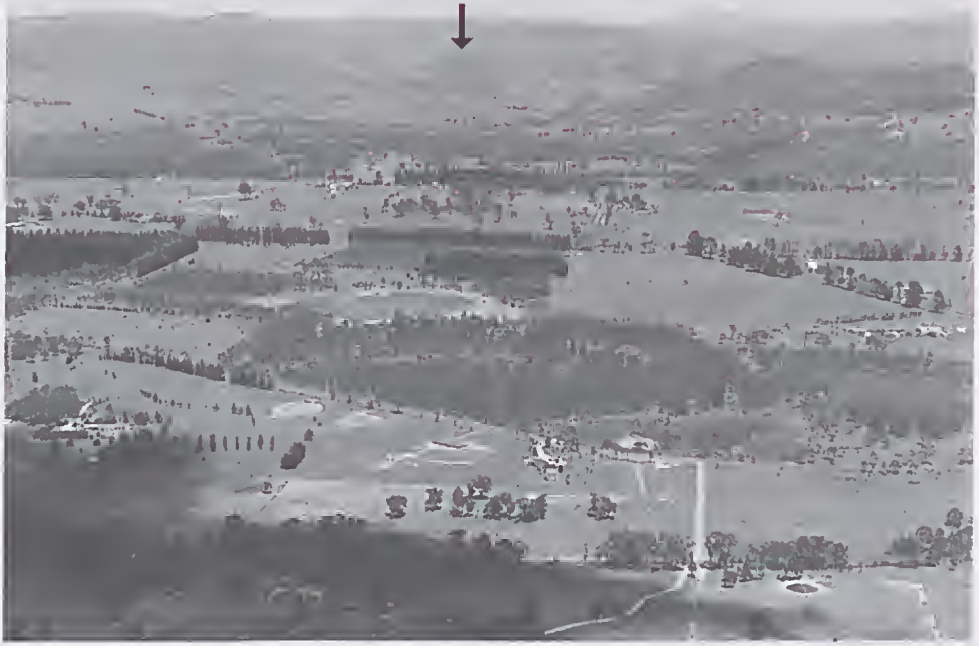

Fig 8. A view of Mt Blaxland (arrowed), at the eastern edge of the Bathurst Granites, from Mt York, the western edge of the Blue Mountains sandstones. If the middle ground, underlain by Permian sediments, was originally timbered as suggested by the eucalypt 'remnants' (lighter tones than exotics), it is difficult to reconcile with Blaxland's original description reproduced on page 808.

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*As recorded for the Central Tablelands botanic subdivision by Harden (1990–93). This *Flora* is also the authority for species nomenclature.

(1981) *Census* were necessary to interpret obsolete nomenclature* and some mistakes may have occurred. A number of taxa were also obtained from Keith & Benson's (1988) description of communities which occur both on and off the Bathurst Granites east of the Great Divide; their presence on granite soils was assumed.

The field survey was mainly limited to roadsides on and to the west of the Great Dividing Range. Most of the roads were travelled, as opportunity arose, during 1992-95. Stops were made where native shrubs were observed. On many roads, particularly on the 'Raglan' and alluvial soil landscapes, shrubs were absent or represented by exotics only and hence, were not sampled. Sample sites were either a small defined area or a stretch of a few kilometres of road. Where access was readily available, e.g. Evans Crown Nature Reserve, off-road sites were also examined. For purposes of comparison, shrubs were also recorded on non-granite sites adjacent to the granite.

Shrubs were recorded from 47 granite sites and nine non-granite sites. Their locations are shown in Fig. 1.

Results

The literature search resulted in a list of 67 native and naturalised shrub taxa, which occurred or were very likely to occur on the Bathurst Granites. Eighty taxa were recorded in the field survey, resulting in a total of 107 taxa for the area (Table 2). In the field survey, an additional 17 taxa were recorded only on non-granite soils adjacent to the granite (though three of these, *Allocasuarina littoralis, Acacia genistifolia* and *Daviesia genistifolia*, had been recorded on granite soils in earlier surveys). Taxa are listed in Appendix I.

Table 2. Numbers of shrub taxa recorded for the Bathurst Granites

	Previous surveys	**Roadside surveys**	**All surveys**
Native	61	60	87
Naturalised	6	20	20
Total	67	80	107

A number of shrubs previously recorded in the granite were not observed in the roadside survey. However, most of the uncommon shrubs, i.e. recorded at only one site, had not been previously recorded on the granite, e.g. *Polyscias sambucifolia, Acacia gladiiformis, Dillwynia cinerascens, Baeckea utilis, Pomaderris betulina* and *Pimelea stricta*. The most common shrubs, i.e. those occurring at many of the roadside sites, were exotics. *Rubus* spp. (blackberries) occurred at 77% of granite sites, *Crataegus monogyna* (53%), *Malus* sp. (53%) and *Rosa rubiginosa* (70%). These figures probably underestimate exotic frequencies as sites with exotics only were not sampled. The most commonly recorded natives were *Acacia dealbata* (77% of granite sites) and *Cassinia arcuata* (68%).

The proportion of exotics was higher in the field survey than was suggested by the

*Current nomenclature for '*Acacia crassiuscula*' and '*Leptospermum stelligerum*' could not be found. *Dodonaea lobulata* is not recorded for the Central Tablelands (Harden 1990–1993) and was presumed to be a misidentification.

results of earlier surveys (though this was probably a consequence of lesser interest in exotic species in the earlier works, rather than an increase in recent times). Exotics comprised almost 20% of the total granite shrub flora (Table 2) and 25% of the shrubs recorded in the field survey (Table 3), a higher proportion than on non-granite sites. Table 3 also shows that almost half of the naturalised taxa were restricted to the granite, whereas none was restricted to adjacent non-granite sites.

Native species were more likely to be recorded from more rugged terrain, *viz.* 'Rocks', 'Pine Mountain' (e.g. Evans Crown, Fig. 3B) and adjacent non-granite soil landscapes. These areas were usually the least disturbed by agricultural activities and trees were often present. Native species were not observed on the alluvial landscapes though exotics were present (Table 4). Mean numbers of native taxa per site appeared to be inversely proportional, and naturalised taxa proportional, to the degree of disturbance: alluvial > 'Raglan' > 'Bathurst' > 'Rocks' > 'Pine Mountain' and non-granite landscapes (Table 4). When total numbers of taxa recorded on each landscape are considered (Table 4), the relationships are less clear with a tendency for the more intensively sampled landscapes to have a higher number of taxa.

Table 3. Numbers* of shrub taxa rcorded on different substrates in the roadside survey

	On granite only	On both granite and non-granite	On non-granite only	Total granite	Total non-granite	Total all substrata
Native	22	36	17	58	53	75
Naturalised	11	9	0	20	9	20
Total	33	45	17	78	62	95

*The apparent discrepancy between numbers in this and the previous table is due to *Bursaria* spp. being recorded here as one taxon (It was not possible to identify beyond genus level at all sites in the field survey)

Discussion

Despite the passing of 180 years, the present landscape still has some affinities with descriptions of it at the time of settlement. Evans Crown (Figs 3A and 3B) retains its tree cover as do a number of other rocky hills such as Pine Ridge, where *Callitris endlicheri* still occurs (Fig. 9). Scenes with scattered eucalypts, such as those shown in Figs 4 and 5, can still be seen. The native grasslands of the Bathurst area are long gone, having been replaced by naturalised species, horticultural crops and/or trees. According to Barker (1992 p. 34),

> *... when one also considers the introduction of exotic species - orchard, poplars, willows and elms, amongst others - it becomes certain that there are more trees on the local plains now than there were when Bathurst was founded ...*

The written and pictorial historical records cited appear to satisfy most of Forman & Russell's (1983) criteria for evaluating historical data in ecology.* However, some exaggeration is possible; e.g. Blaxland's description of the granite country from Mt Blaxland (p. 6). Even allowing for some exaggeration and selective reporting, the

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*1. First- or second-hand observation; 2. Purpose, or possible bias, of the statement
3. Author's knowledge of the subject; 4. Context of the statement.

records suggest that the granite landscape had timbered hills (particularly in the vicinity of the Great Dividing Range), slopes with grassy woodlands, and flats (and near Bathurst, the adjacent slightly undulating country) with grasslands. Shrubs were apparently infrequent except on the more rugged country. Apart from the presence of exotic shrubs, this is in accordance with their distribution today as recorded in the roadside shrub survey (Table 4).

As far as the occurrence of shrubs and trees on the adjacent non-granite country is concerned, Clunies Ross' (1898 p. 470) observations are still valid:

> *... On approaching the boundaries of the granite in certain directions one finds some new plants, but the variety is still limited until one reaches the Silurian rocks. Then a change is at once noted. Instead of open land, with scattered trees and well grassed, one finds numerous shrubs and stunted gum-trees, with detached tussocks of coarse grass ...*

These observations are supported by the roadside shrub survey (Table 4).

On Hayden's (1971) map of the supposed pre-settlement vegetation of NSW, most of the Bathurst Granites west of the Great Dividing range was shown as having supported an *Eucalyptus melliodora* - *E. blakelyi* (presumably grassy) woodland. Forests of *E. fastigata* - *E. viminalis* and *E. macrorhyncha* - *E. rossii* were shown on and to the east of the Great Dividing Range. The scale of the map was too small to show most of the forested hills (which are present today [e.g. see National Trust of Australia 1987] and presumably occurred previously) within and at the margins of the granite. These, together with the supposed locatation of the original grasslands, are shown on a larger-scale map (Anon. 1974) of the western part of the granite.

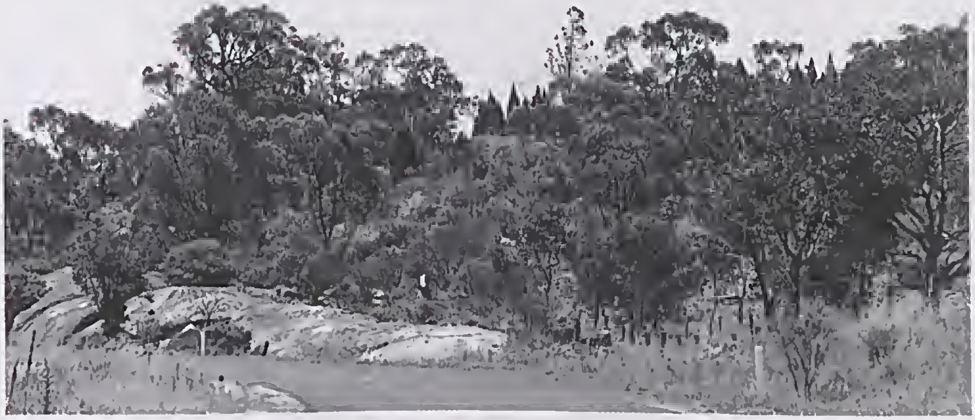

Fig 9. Shrubs are common on this rocky outcrop on Pine Ridge road, c.15 km west of Bathurst. This area is presumed to be the same one, which - due to the presence of *Callitris endicheri* - attracted Governor L. Macquarie in 1815 and botanist/explorer, A. Cunningham, in 1822 (McMinn 1970). Macquarie recorded his visit as follows:

> *... The rest of the party accompanied me on horseback as far as Pine Hill about 7 miles to the westward of Mt. Pleasant* [Stewart]. *Our ride to this place was a very rough one over a succession of steep hills and deep valleys alternately. On reaching Pine Hill we saw the pine-tree of this country in great numbers and of a considerable height, but of no great circumference, none of them being above one foot in diameter* ... (p. 103, 1956 reprint).

Table 4. **Occurrence of shrub taxa[1] on non-granite and granite soil landscapes**

	Non-granite landscapes	Pine Mountain	Rocks[2]	Bathurst	Raglan	Evans Plains & Macquarie[3]
No. of sites	9	3	24	18	2	0
(a) Mean number of taxa per site:						
Native	13.3	12.7	8.3	6.3	1.0	-
Naturalised	2.2	2.3	4.0	4.8	5.5	-
Total	15.5	15.0	12.3	11.1	6.5	-
(b) Number of taxa recorded for each landscape:						
Native	53	30	44	33	2	-
Naturalised	9	5	15	17	8	-
Total	62	35	59	50	10	-

1. *Bursaria* spp. counted as one taxon
2. Includes Marrangaroo and Round Mount soil landscapes in the vicinity of the Great Dividing Range
3. No native shrubs were observed on these landscapes; hence, no sites were sampled

On the western section of the Bathurst Granites, historical sources and the shrub survey suggest that the frequency and diversity of native shrubs were (and are) relatively:

1. low over much of the granite—particularly on lower-lying country
2. high on rocky granite hills, and
3. higher on the adjacent non-granite hilly country.

Keith & Benson's (1988) descriptions of current vegetation on the eastern part of the Bathurst Granites - including an outlier east of Jenolan Caves - also supports (1) and (2).

A survey of rocky outcrops (6 granite and 13 non-granite) in the central southern part of NSW by Norris & Thomas (1991) suggest that these observations may be of general applicability. Only four shrub species were recorded on the granite outcrops compared to 49 on sandstone. Slate and rhyolite substrates also had low numbers of shrub species but only one site of each was sampled. Unlike many rocky outcrops of the Bathurst Granites, most of the outcrops in that survey were of low relief.

Further evidence for the reduced frequency of shrubs on granite soils comes from the bimble box-pine (*Eucalyptus populnea–Callitris glaucophylla*) woodlands of western NSW. The frequency of species of *Dodonaea*, *Senna* and *Eremophila*, as well as *Callitris*, has been increasing since the late 1800s such that most of this originally grassy woodland is now a shrub woodland (Anon. 1969). Small areas of granite soil - mainly 'Penshurst' and 'Warrowie' land systems (Johnston & Milthorpe 1984) - have been largely unaffected by these species, though in recent years *Acacia* spp. have been increasing (R. Harland, pers. comm.)

The increased frequency of shrubs on the non-granite soils near Bathurst is probably a consequence of the shallow, low fertility soils. These factors are associated with dry sclerophyll forests with moderately to well-developed shrub layers in other areas (e.g. Moore 1953, Biddiscombe 1963). As many of the shrub species—particularly those restricted to non-granite sites (Appendix 1B)—are xeromorphic, the limiting factor may be phosphorus as proposed by Beadle (1981). However, in a review of shrub increase on rangelands, Archer (1994) noted that, compared to grasses, shrubs are better able to use the resources of sites with shallow and/or rocky soils by exploiting fissures in the underlying barriers.

Soils of the more rugged granite country ('Pine Mountain' and 'Rocks' soil landscapes) are not of markedly higher fertility than adjacent non-granite areas.

Waterholding capacity and chemical fertility, for example, are low in both groups, though the non-granite soils tend to have lower pH (Table 1). As 36 native shrub taxa were common to both granite and non-granite soils (Table 3), it is likely that low fertility is at least partly responsible. However, as 11 native shrub taxa were restricted (at least in the roadside survey, Table 3) to granite soils suggests other factors were operating. As many shrubs only occurred on drainage lines or near rock outcrops, enhanced moisture availability may explain the presence of some species on the more rugged granite sites. Drainage lines, including gullies, were also sites of exotic (non-xeromorphic) shrub increase on these granite soil landscapes.

On the lower slopes and alluvial flats where soils are deeper and generally more fertile (Table 1), native shrubs were uncommon. Only two species, *Cassinia arcuata* and *Acacia dealbata*, were recorded on the 'Raglan' soil landscape and none on 'Macquarie' or 'Evans Plains'. Exotic shrubs, however, did occur on roadsides, gullies and along watercourses and have been present on the granite country for a considerable time; e.g. Maiden & Cambage's (1909, p. 132) report of 'Sweet Briar' (presumably *Rosa rubiginosa*) 'in the greatest profusion' at the junction of Hobby's Creek and the Fish River.

Some native shrubs can be established - at least from tubestock (e.g. Semple et al. 1995) —on these areas. Whether all those recorded (Appendix 1A) can be established in this way is unknown—particularly in view of the changes that have occurred since settlement: e.g. applications of superphosphate, changed drainage, grazing and introduction of exotic forbs and grasses. Direct seeding of trees and shrubs has not been very successful on the Bathurst Granite. In trials reported by Semple & Koen (in press), low seedling survival was partly attributed to the abundance of wingless grasshoppers, *Phaulacridium vittatum* Sjöstedt, which is thought to be due to changed conditions since settlement (Semple et al. 1995, Davidson 1995). Competition from herbaceous species was the main reason for low survival of seedlings.

The absence of native shrubs in the original grasslands and lower slope woodlands is often attributed to burning by Aborigines. Examples of this general practice from the early literature have been provided by Ryan et al. (undated) and for this area, in the reports of Antill (1965) and Darwin (1968). However, to prevent suppression of grass fuel by shrubs, burning would need to have been frequent. For example, one of the most widespread native shrubs on the granite, *Cassinia arcuata*, is killed by fire but regenerates rapidly from seed afterwards (Semple & Koen 1993) and can set seed two years later (Parsons 1973). The role of fire in maintaining grasslands at the expense of shrublands, may have been over-estimated. In order to have a fire, continuous fuel (grasses) must be present, i.e. in order to have a grassland fire, you must first have a grassland (Archer 1994).

The most likely explanation for the relative abundance of shrubs on rocky hills, *v.* lower slopes is the presence/absence of a continuous sward of perennial grasses. The absence of this feature on non-granite soils adjacent to the granites was noted by Clunies Ross (1898, cited earlier). In woodlands further west, Biddiscombe (1963) observed that native grasses had difficulty establishing on stony sites following clearing and were soon suppressed by shrubs. The necessity of a competitive stand of perennial grasses for preventing shrub recruitment in western NSW was suggested by Booth et al. (1996) and for preventing *Cassinia arcuata* recruitment in central western NSW, by Campbell et al. (1990). In the latter study it was noted that on non-arable land, a competitive (exotic) pasture could not be established due to the low fertility soils.

It is suggested, therefore, that soils of low fertility (e.g. rocky, shallow, low nutrient status, low water-holding capacity) are incapable of supporting a continuous sward of perennial grasses. Gaps provide regeneration niches for shrubs which have low nutrient requirements (e.g. xeromorphs) and/or are better able to exploit the limited supply of nutrients. Fire may have assisted in maintaining a low frequency of shrubs provided sufficient fire-tolerant perennial grasses were present to outcompete shrub seedlings.

Conclusions

Numbers of shrub taxa on the Bathurst Granites are not high. Previous surveys and a roadside survey of the western part of the granite recorded 107 taxa. Diversity and numbers of shrubs were highest on the more rugged parts of the granite. Very few native shrubs were recorded on the low-lying areas—particularly in the vicinity of Bathurst. There is some evidence that shrub numbers and diversity on granite, compared to surrounding areas, is low in other parts of NSW.

Historical records suggest that shrubs were infrequent—apart from perhaps the more rugged areas (where little information is available)—at the time of settlement. These records also suggest that much of the granite, apart from areas of higher elevation, supported open grassy woodlands—probably more open than suggested by present 'remnants'—and, near Bathurst, grasslands.

Exotics comprise about 20% of the present shrub flora of the Bathurst Granites. Diversity and numbers of exotic shrubs are highest on areas of the granite that have been subjected to the most disturbance. Gullies, in particular, are major sites of exotic shrub increase.

Non-granite areas adjacent to the Bathurst Granite commonly support high numbers and a high diversity of native shrubs. This observation, together with the general absence of shrubs on the most fertile parts of the granite, suggest that shrubbiness is a consequence of low fertility and, in particular, the inability of low fertility sites to support a dense sward of perennial grasses.

Though shrubs may be desirable components of on-farm tree plantations on the Bathurst Granites, the resulting vegetation is unlikely to represent the pre-European settlement vegetation, except on rocky hills. The latter sites would also be the most suitable for direct seeding due to reduced herbaceous competition. However, environmental changes associated with European settlement, e.g. erosion, increased fertility in some areas and increased frequency of wingless grasshoppers, may increase or decrease the likelihood of success at particular sites.

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Appendix I: Shrubs and shrub-like plants recorded A) on the Bathurst Granites and B) on adjacent non-granite areas only

Family/Species *naturalised in the region *? possibly naturalised	Habit and height (in metres where stated) from Harden (1990–1993). All are shrubs or have shrubby form unless otherwise stated	Source A to E refer to previous surveys (see footnote 1) x = roadside survey (no voucher) v = roadside survey (voucher identified by the National Herbarium)	Presence (✓) /absence (-) on granite soil landscapes^2				Roadside survey		
								Frequency^3	
							on granite sites /47	on non granite sites Ordivician, Silurian & Devonian /8	Permian /1
			Pm	Ro	Ba	Ra			
A) Species recorded on granite									
AMYGDALACEAE									
**Prunus* spp.	small tree	x	-	✓	✓	✓	14	0	0
APIACEAE									
Platysace lanceolata	1.5	A	-	-	-	-	-	-	-
ARALIACEAE									
Polyscias sambucifolia subsp. C	5	v	-	✓	-	-	1	0	0
ASTERACEAE									
Cassinia aculeata	2.5	v	-	✓	-	-	1	0	1
C. arcuata	2	x	✓	✓	✓	✓	32	7	0
C. laevis	3	B	-	-	-	-	-	-	-
C. longifolia	2.5	x	✓	-	✓	-	4	2	0
C. quinquefaria	3	vADE	✓	✓	✓	-	19	4	1

Ozothamnus diosmifolius	5	x	✓	-	✓	-	2	1	0
CASUARINACEAE									
Allocasuarina diminuta subsp. *diminuta*	5	v	-	-	✓	-	1	2	0
A. littoralis	15 (tree)	D	-	-	-	-	0	0	1(v)
DILLENIACEAE									
Hibbertia diffusa	0.3	E	-	-	-	-	-	-	-
H. obtusifolia complex	0.6	xCD	✓	✓	✓		15	5	0
H. riparia complex	0.6	v	-	-	✓	-	1	0	0
EPACRIDACEAE									
Brachyloma daphnoides	1.5	xBC	✓	✓	✓	-	18	5	0
Epacris microphylla	1	v	-	✓	-	-	1	0	0
Leucopogon lanceolatus	3	A	-	-	-	-	-	-	-
Lissanthe strigosa	0.7	vA	-	-	✓	-	4	1	0
Melichrus urceolatus	1.5	x	-	✓	-	-	2	0	0
Monotoca scoparia	1.2	vB	✓	-	-	-	1	3	1
Styphelia triflora	2	xB	✓	✓	✓	-	6	5	0
EUPHORBIACEAE									
Beyeria viscosa	4	B	-	-	-	-	-	-	-
FABACEAE: Mimosoideae									
**Acacia baileyana*	6	x	-	-	✓	-	3	0	0
A. buxifolia	3	xE	-	✓	✓	-	5	2	0
A. dealbata	15 (tree)	xBCDE	✓	✓	✓	✓	36	7	1
A. falciformis	10	vBC	✓	✓	-	-	10	0	1

A. genistifolia	3	E	-	-	-	-	0	1(x)	0
A. gladiiformis	3	v	-	-	✓	-	1	0	0
A. implexa	12 (tree)	v	✓	✓	✓	-	7	1	0
A. lanigera	3	x	✓	-	✓	-	7	2	0
A. mearnsii	10 (tree)	B	-	-	-	-	-	-	-
A. melanoxylon	30 (tree)	xABCD	✓	✓	,	-	10	0	1
A. obliquenervia	15	A	-	-	-	-	-	-	-
A. penninervis	8 (tree)	vCD	-	✓	-	-	3	2	0
A. ulicifolia	2	vE	-	-	✓	-	2	0	0
A. verniciflua	5	vC	✓	✓	✓	-	7	1	0
A. vestita	4	x	✓	✓	✓	-	5	1	0
FABACEAE: Faboideae									
Bossiaea buxifolia	1.3	C	-	-	-	-	-	-	-
B. obcordata	2	B	-	-	-	-	-	-	-
**Chamaecytisus palmensis*	4x	-	✓	✓	-	8	1	0	
**Cytisus scoparius*	2.5	xC	-	✓	✓	-	5	0	0
Daviesia genistifolia	2	E	-	-	-	-	0	2(v)	0
D. latifolia	5	xABCE	-	✓	-	-	8	1	1
D. leptophylla [*D. virgata*]	2	x	-	✓	✓	-	3	6	0
Dillwynia cinerascens	1.5	v	-	✓	-	-	1	0	0
D. phylicoides complex	1.5	vC	✓	✓	✓	-	17	5	0
**Genista monspessulana*	3	x	-	✓	✓	-	4	0	0
Hardenbergia violacea	<2	xBCD	-	✓	✓	-	10	4	0
Indigofera adesmiifolia	1.5	v	-	✓	✓	-	3	0	0

I. australis	2.5	xABCDE	✓	✓	✓	-	5	1	0
Oxylobium ilicifolium	3	A	-	-	-	-	-	-	-
Pultenaea procumbens	<2	vE	-	✓	✓		2	1	0
Swainsona galegifolia	1	AD	-	-	-	-	-	-	-
GOODENIACAE									
Dampiera purpurea [D. brownii]	1	E	-	-	-	-	-	-	-
LAMIACEAE									
Westringia eremicola	1.5	CE	-	-	-	-	-	-	-
MALACEAE									
**Contoneaster franchetti*	3	v	-	✓	✓	-	3	1	0
**C. glaucophyllus*	1+	v	-	-	✓	-	1	1	0
**C. pannosus*	3	v	-	✓	-	-	2	1	0
**Crataegus monogyna*		xB	✓	✓	✓	✓	25	1	1
**Malus* spp. (apple)	small tree	x	✓	✓	✓	✓	25	3	1
**Pyracantha angustifolia*	3	v	-	✓	✓	-	9	0	0
**P. fortuneana*		v	✓	✓	✓	-	3	0	0
**P. rogersiana*	3	v	-	✓	✓	✓	10	0	0
MYRTACEAE									
Baeckea utilis	3	v	-	✓	-	-	1	0	0
Callistemon sieberi		vD	-	✓	-	-	1	0	0
Calytrix tetragona	2	xB	✓	-	✓	-	2	2	1
Kunzea parvifolia	1.5	v	-	✓	✓	-	4	2	0
Leptospermum myrtifolium	3	v	✓	✓	-	-	6	0	1
L. polygalifolium [L. flavescens]	7	D	-	-	-	-	-	-	-

L. trinervium [*L. attenuatum*]	5	E	-	-	-	-	-	-	-	
OLEACEAE										
**Ligustrum lucidum*	10	vB	-	✓	✓	-	2	0	0	
**L. sinense*	3	x	-	-	✓	-	1	1	0	
**Olea europaea* subsp. *africana*	15 (tree)	v	-	-	-	✓	1	0	0	
PITTOSPORACEAE										
Bursaria lasiophylla	2.5	v	}							
B. longisepalea	2	v	}	✓	✓	✓	-	18	2	1
B. spinosa	8	vABCE	}							
PROTEACEAE										
Banksia marginata	12	xABDE	-	✓	-	-	9	0	0	
Grevillea acanthifolia	3	E	-	-	-	-	-	-	-	
G. arenaria	3	vBC	✓	✓	-	-	3	1	0	
*?*G. rosmarinifolia*	2	v	-	-	✓	-	1	0	0	
G. triternata	1	D	-	-	-	-	-	-	-	
Hakea microcarpa	2	vE	-	✓	-	-	1	0	0	
Lomatia myricoides	5	vABCD	-	✓	-	-	2	0	1	
L. silaifolia	2	B	-	-	-	-	-	-	-	
Personia linearis		vB	✓	-	✓	-	2	0	1	
P. oxycoccoides		A	-	-	-	-	-	-	-	
RHAMNACEAE										
Cryptandra amara	1	E	-	-	-	-	-	-	-	
Discaria pubescens [*D. australis*]	2.5	E	-	-	-	-	-	-	-	
Pomaderris angustifolia	3	vC	-	✓	-	-	1	0	0	

P. betulina	3	vC	-	✓	-	-	1	0	0
P. eriocephala	3	vC	✓	-	-	-	1	0	0
ROSACEAE									
**Rosa rubiginosa*		xBCD	✓	✓	✓	✓	33	2	1
Rubus parvifolius		vDE	-	✓	-	-	6	0	0
**Rubus* spp. (blackerrries)		xBC	✓	✓	✓	-	36	5	1
RUTACEAE									
Correa reflexa [*C. speciosa*]	1.5	E	-	-	-	-	-	-	-
Eriostemon myoporoides	2	D	-	-	-	-	-	-	-
E. trachyphyllus	7	vB	✓	-	-	-	1	0	0
Zieria cytisoides	3	v	✓	-	-	-	1	0	0
SANTALACEAE									
Exocarpos cuppressiformis	8	xABCD	✓	✓	✓	-	18	6	1
E. strictus	3.5	xCE	✓	✓	-	-	4	0	0
SAPINDACEAE									
Dodonaea viscosa subsp. *angustifolia*	5	x }	✓	✓	-	-	2	0	0
D. viscosa subsp. *angustissima*	4	v } ABC	✓	✓	✓	-	5	2	0
D. viscosa subsp. *cuneata*	3	x }	✓	✓	-	-	2	0	0
SIMAROUBACEAE									
**Ailanthus altissima*	to 8 (tree)	B	-	-	-	-	-	-	-
SOLANACEAE									
**Lycium ferocissimum*	4	x	-	✓	✓	✓	15	0	0
THYMELAEACEAE									
Pimelea stricta	1.5	v	-	✓	-	-	1	0	0

VIOLACEAE									
Hymenanthera dentata	4	vB	-	✓	✓	-	7	0	1
TOTAL NO. OF TAXA RECORDED			**107**	**35**	**59**	**50**	**10**	**78**	**48**
B) 5pecies recorded on adjacent non-granite areas only									
ARALIACEAE									
Astrotricha longifolia	3	v	-	-	-	-	0	1	0
EPACRIDACEAE									
Leucopogon attenuatus	0.6	x	-	-	-	-	0	1	0
L. microphyllus var. *pilibundus*	1	v	-	-	-	-	0	1	0
EUPHORBIACEAE									
Phyllanthus hirtellus	0.8	x	-	-	-	-	0	1	0
FABACEAE									
Acacia gunnii	2	v	-	-	-	-	0	1	0
A. paradoxa	4	x	-	-	-	-	0	2	0
A. terminalis	5	v	-	-	-	-	0	2	0
Pultenaea subternata		x	-	-	-	-	0	2	0
P. sp. F		v	-	-	-	-	0	1	0
MYRTACEAE									
Kunzea ericoides	5	x	-	-	-	-	0	1	0
Leptospermum continentale	2	v	-	-	-	-	0	0	1
L. multicaule	<2	x	-	-	-	-	0	1	0

PROTEACEAE									
Grevillea ramosissima	3	x	-	-	-	-	0	1	0
Hakea decurrens	3	v	-	-	-	-	0	2	0

1. Sources other than roadside survey:

A. Keith & Benson (1988): *E. fastigata–E. dalrympleana–E. viminalis*; Mt. Blaxland complex; *E. melliodora–E. viminalis; E. radiata–E. dalrympleana* communities east of the Great Dividing Range

B. National Parks & Wildlife Service (undated): Plant species list for Evans Crown Nature Reserve

C. Wakefield (1994): River Lett Hill & Rocks Creek

D. Maiden & Cambage (1909): Mt. Blaxland to O'Connell

E. Clunies Ross (1898): granite areas near Bathurst

2. Soil landscapes as defined by Kovac et al. (1990)

Pm = Pine Mountain Ro=Rocks (including Marrangaroo and Round Mount landscapes of King 1993, 1994)
Ba = Bathurst Ra = Raglan

3. Frequencies are relative only as sample size varied and sites with only naturalised shrubs were not sampled.

An analysis of plant communities at Coomonderry Swamp with comparisons to other wetlands on the south coast of New South Wales

N.H. de Jong

de Jong, N.H. (Department of Biological Sciences, University of Wollongong, Wollongong, New South Wales, Australia 2522) 1997. An analysis of plant communities at Coomonderry Swamp with comparisons to other wetlands on the south coast of New South Wales Cunninghamia 5(1): *81–128.* Coomonderry Swamp (34°48'S, 150°44'E) is, at 670 ha, the largest freshwater, coastal wetland in southern New South Wales and represents a substantial percentage of wetland of this type. In this study the floristic composition and relationships between plant communities at Coomonderry Swamp are described. Comparisons are made with a diversity of other local wetlands in order to assess the value of Coomonderry Swamp as a reference site, to analyse those broad characteristics of the environment associated with changes in floristics in coastal wetlands of the region, and to assess the distribution and abundance of key indigenous plant species over a range of wetland conditions.

Seven communities were defined by cluster analysis at Coomonderry Swamp with 11 'local variants' recognized within these. Plant community differentiation at Coomonderry Swamp was considered to be related to the structure of vegetation, drainage and nutrient status of soils, and to the influence of anthropogenic disturbance.

Over 200 plant species were identified for Coomonderry Swamp and its humic soil margins. A number of these are of regional significance. However the greatest importance of Coomonderry Swamp lies in the diversity of its plant communities. Relatively undisturbed, permanent freshwater swamps are virtually non-existent in the Sydney region and are poorly represented on the south coast of New South Wales. Some communities, well represented at Coomonderry Swamp, such as native sedgeland and swamp mahogany open-forest, are regionally rare.

Cluster analysis of communities from eight other local wetlands resulted in the identification of a further four community types with salinity being the major additional environmental component differentiating these groups from those described for Coomonderry Swamp.

Introduction

Ninety percent of all coastal wetlands in New South Wales are found north of Sydney (Adam et al. 1985; Pressey & Harris 1988; ANCA 1996) and scientific focus has consequently been on the extensive dunal wetlands of the Central and North Coast (see Pressey & Harris 1988; Jacobs & Brock 1993 for review). Freshwater wetlands on the south coast of New South Wales have been poorly studied (but see Porter 1990). Yet their relative rarity enhances their worth; as habitat for fauna, as drought refuge for migratory and nomadic birds, and as sites harbouring rare species.

Although there has been a general recognition by authorities of these values, south coast wetlands continue to be under threat. Impacts of development on wetlands are regularly debated in the local media, although much damage to wetland margins and infilling of ephemeral and smaller permanent water bodies is seldom reported (pers. obs.). Debate often emphasises the need for information, not just about complex issues such as effects of disturbance, or methods of restoration, or so called 'wetland compensation', but often about the basic data - what animals and plants are present?

Despite being the largest freshwater wetland on the New South Wales south coast, Coomonderry Swamp has remained essentially unexplored, although bird surveys and inventories have noted its ecological significance (Goodrick 1970; Moss 1983; Lawler & Porter 1990). This recognition resulted in protection of the central third of the wetland within Seven Mile Beach National Park, but urban and agricultural impacts along some margins of the wetland have greatly increased in recent years.

This study describes in detail the plant communities at Coomonderry Swamp. These communities are then assessed in a broader context. Comparisons are made with eight other local wetlands which differ markedly in disturbance regime and geomorphology, and also with wetlands described in some other published reports. These include studies of: estuarine communities at Jervis Bay (Clarke 1993; Mills 1995) and the Minnamurra River (Carne 1989), foreshore vegetation of Lake Illawarra (Yassini and Clarke 1985; Yassini 1985), and upland swamp plant assemblages (Kodela & Hope 1992; Keith & Myerscough 1993; Stricker & Wall 1995; Kodela et al. 1996). Relationships are also examined between wetland environments of the Sydney region (Benson & Howell 1994) and with similar coastal environments of the central coast of NSW (Myerscough & Carolin 1986).

Comparison were made with other wetlands to allow: (i) better insight into the relationship between distributions of communities (or species) and environmental factors (cf. Grime et al. 1988); (ii) better determination of the distributions of species which may be poorly known e.g. those belonging to the Juncaceae, Cyperaceae and Poaceae (Adam 1981; Adam et al. 1988; Clarke 1993; Johnson 1993); and (iii) better evaluation of Coomonderry Swamp as a reference site.

In this paper the term 'community' is applied to vegetation assemblages in the sense described by Austin (1991) i.e. 'relatively homogeneous units within a continuum'. In response to the need to work towards a broader framework of community classification of wetlands in New South Wales (Adam et al. 1988), the terminologies suggested by Adam et al. (1988) and Zedler et al. (1995) for saltmarsh and adjoining communities; by Myerscough & Carolin (1986) for coastal sand and associated wetland communities; and by Goodrick (1970) for wetlands in general, are used, or at least referred to, where vegetation units are considered to be comparable.

Some communities described emphasise the dynamic nature of wetlands and the requirements for at least some temporal evaluation of vegetation. For example open water and ephemeral communities may occupy the same space, with their alternation being dependent on the particular regime of environmental conditions. In this report clustering and ordination techniques were used to correlate floristic patterns to environmental variables on the broader scale of differences found within and among the variety of wetlands surveyed. Hypotheses concerning the causes of finer scale temporal and spatial changes of vegetation within Coomonderry Swamp will be considered elsewhere (de Jong unpubl. data).

This report does not provide an exhaustive list of all community types found in the region. Many wetlands in the area cited in inventories (Adam et al. 1985; West et al. 1985; ANCA 1996), await ecological investigation, and to these must be added numerous ephemeral wetlands and periodically wet environments which have not been mapped or recorded. Omitted from the present report are examples of coastal wet heaths (coastal bogs, Goodrick 1970) which are located on the margins of Jervis Bay. Analogous communities on the central coast of NSW have been described by Myerscough & Carolin (1986). In addition, a number of saltmarsh assemblages known to occur in the region (see Adam et al. 1988; Clark 1993) are not included.

The objectives of this study were to: (i) provide a detailed survey of the plant species composition, distribution, abundance and structure at Coomonderry Swamp, (ii) give a first account of the floristics at a range of other south coast wetlands, and (iii) compare communities, species richness, and distribution and abundance of key species among local coastal wetlands.

Methods

Study sites

Coomonderry Swamp (34°48'S, 150°44'E) is equidistant between the large south coastal towns of Kiama and Nowra (Fig. 1) and has a catchment of 1530 hectares. It covers approximately 670 hectares, filling a depression stretching for more than five kilometres adjacent to the open-forest vegetation of Seven Mile Beach National Park. Coomonderry is a last vestige of once extensive areas of wetland associated with the Shoalhaven River and Broughton Creek. Almost all of these swamps were drained at various times for grazing purposes with consequent acid-soil problems recently becoming apparent (e.g. Department of Land & Water Conservation 1995). Immediately to the north of Coomonderry Swamp, a portion of what was once Foys Swamp is now a sand mine.

Coomonderry Swamp is a dune-contact wetland although the term 'lake', usually employed in the typology of dunal waterbodies, can hardly be applied to Coomonderry Swamp since it is uniformally shallow (<2 m depth) and rarely supports large areas of open water. Its geomorphology (between dunes and adjacent rock) and chemistry (salinity usually <500 mgL^{-1}) are typical and indicative of dune-contact systems (Timms 1982, 1986, 1988).

No obvious creeks feed into Coomonderry Swamp, yet the wetland responds rapidly to rainfall events and also to periods of drought (de Jong 1997). Inputs of water to Coomonderry Swamp are via: direct rainfall, surface run off and springs from bedrock, subsurface seepage from dune ridges, and groundwater from mounds in sand dunes and from sand-bed aquifers (Mitchell McCotter & Associates Pty Ltd

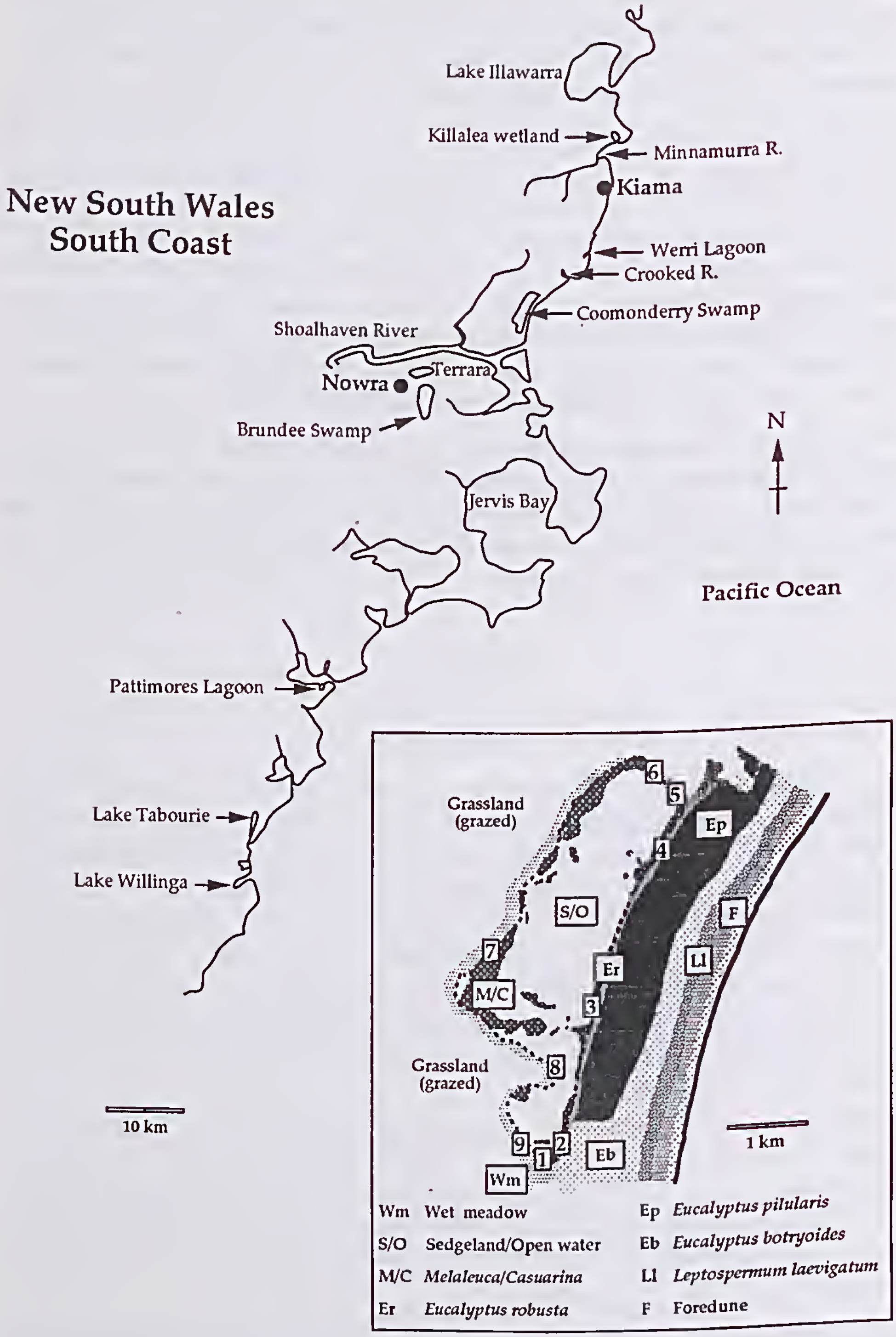

Fig. 1. Locations of wetlands surveyed and other coastal wetlands referred to in the text. Inset: Coomonderry Swamp indicating positions of transects 1–9, and major vegetation types. Based on Mitchell McCotter & Associates Pty Ltd (1991) and de Jong & Kodela (1995).

1991). Outflows occur via a southern drainage channel and by seepage into sand beds at the eastern margin. Hazelton (1992), described the wetland soils as composed of friable organic peat (30 cm) overlying acid peats of depths greater than 100 centimetres. Below the peat, various sandy subsoils overlie Quaternary marine sands.

The comprehensive botanical survey at Coomonderry Swamp involved investigation along nine transects (Fig. 1) supported by general description of floristics in and around the wetland over a three year period. Detailed descriptions of vegetation were also completed at Killalea (the nearest other freshwater wetland) and at a saline wet meadow site, Werri Lagoon (Fig. 1). Preliminary surveys were made at another six wetlands (Fig. 1 & Table 1). Wetlands were chosen to represent the three major geomorphological divisions: estuarine, floodplain and dunal (Adam et al. 1985). Difference among wetlands included salinity, hydrology, soil type, size, and the nature and degree of anthropogenic disturbance (Table 1).

Detailed maps, locations, management objectives, landform types, land tenure, wetland size, bird habitat and conservation status of the wetlands surveyed have variously been described in inventories and other publications (Blachford & Reeks 1976; Bell & Edwards 1980; Moss 1983; Adam et al. 1985; West et al. 1985; Gibson 1989; Lawler & Porter 1990; Porter 1990; Chafer & Marthick 1995; Shoalhaven City Council 1995; ANCA 1996; Young et al. 1996).

Survey design

Belt transects (1 m width) were generally situated along the elevation gradient, beginning on the landward side in visually homogeneous units of either woodland, meadow or sand dune and ending in the deepest part of the wetland, often in open water or homogeneous units of deep water vegetation. Discontinuities in vegetation commonly varied in response to changes along the elevation gradient and consequently transects varied in length (Table 1). At Terrara, a drained and grazed swamp, there was no obvious elevational change.

Estimates of percentage cover (0, < 10%, ≥ 10%) were made for all plant species in contiguous, 2 m × 1 m quadrats along each transect. Structural characteristics of the vegetation were recorded and the following classifications were used (after Specht 1981): (i) herbaceous layer: < 1 m, (ii) reed/sedge: 1–2 m, (iii) shrubland: 1–4 m, (iv) woodland: trees > 4 m.

Soils at c. 20 m intervals along each transect were visually classified as either 'peat' (almost completely organic), 'humic' (> 50% organic but with some sand), 'sandy' (< 50% organic), 'sand' (virtually no organic material) and 'lateritic' (a soil type found only on the western upper margin of Brundee Swamp). Where possible, water salinity and pH were recorded at c. 20 m intervals. Salinities were measured using a temperature—compensated salinity meter and pH using Universal Indicator paper or field pH meter. At Coomonderry Swamp, elevations along transects were recorded at 2 m intervals. These were determined using an autolevel and from water depths. At this site, elevations on all transects could be related. At other sites water depths were recorded at 2 m intervals along transects at the time of sampling and estimates were made of relative elevations above water level.

Table 1 Characteristics of wetland sites and extent of vegetation study.

Site	Size (km^2)	Geomorphology	Disturbance history	Survey
Killalea Swamp (375) (SB009NS) 34°34'S, 150°52'E	0.2	Fresh-brackish, dunal swamp.	Probably cleared. Grazed until recently. Wholly protected within State Recreation Area.	Comprehensive: 3 transects and perimeter survey (110, 72, 56 m).
Werri Lagoon (371a) 34°44'S, 150°50'E	0.8–6.2 (17.0)	Estuarine lagoon.	Cleared and grazed freehold land. Drained regularly - intermittently open.	Comprehensive: 3 transects and perimeter survey (56, 50,104 m).
Crooked River 34°46'S, 150°49'E	0.2–0.5 (28.6)	Estuarine lagoon.	Degraded forest, cleared and grazed freehold land. Silted entrance - intermittently closed.	Preliminary: 2 transects: forest to saltmarsh (80, 222 m).
Coomonderry Swamp (370) (SB006NS) 34°48'S, 150°44'E	5.9–6.7 (15.3)	Fresh, dunal swamp.	Western margin: cleared and grazed freehold land. Eastern margin relatively undisturbed.	Comprehensive: 9 transects and perimeter survey (204, 210, 120, 130, 290, 72, 96, 120, 120 m).
Terrara Swamp 34°53'S, 150°39'E	1.7–2.0	Fresh, floodplain swamp.	Extensively drained, fallow or grazed freehold land.	Preliminary: 1 transect in wet meadow (60 m).
Brundee Swamp (344) 34°55'S, 150°39'E	4.0	Fresh–brackish, floodplain swamp.	Extensively drained, fallow or grazed freehold land. Some undisturbed, wooded wetland.	Preliminary: 2 transects: forest to wet meadow, dry meadow to tea-tree (110, 200 m).
Pattimores Lagoon (294) 35°16'S, 150°30'E	0.5	Saline, dunal swamp.	Largely undisturbed margin, but subject to periodic estuarine inflow via a canal.	Preliminary: 1 transect: forest to deep water (98 m).
Lake Tabourie (272) 35°27'S, 150°25'E (43.0)	1.4	Estuarine lake.	10–25% cleared, some revegetated. Uncleared margin in State Forest. Silted entrance.	Preliminary: 1 transect: sand dune regrowth-deep water (144 m).

Table 1 continued

Willinga Lake (260) 35°30'S, 150°23'E	0.3	Estuarine lake.	Increasing development on margins. Entrance intermittently closed. Some undisturbed margin.	Preliminary: 1 transect: forest to deep water (260 m).

Site: Wetland reference numbers (Adam et al. 1985; ANCA 1996) shown in brackets. Size: Ranges are given where maps and/or references differ. Variations indicate the arbitrary definition of wetland boundaries. Catchment size (if known) is shown in brackets. Survey: Length of transects shown in brackets in the order named (see Fig. 4). Sources: Bell & Edwards 1980; Moss 1983; Adam et al. 1985; West et al. 1985; Lawler & Porter 1990; Chafer & Marthick 1995).

Transect analyses at Coomonderry Swamp

TWINSPAN analysis (Hill 1979; Gauch 1982) was used to cluster quadrats along each of the nine transects at Coomonderry Swamp (Table 1) on the basis of plant species compositional similarity. A standard stopping rule for numbers of divisions was applied for all transects, identifying relatively homogeneous units of vegetation (termed community transect units). An example of how TWINSPAN defined these units along one transect at Coomonderry Swamp is shown in Fig. 2 (see also de Jong 1997). An alternative clustering strategy used for comparison (Jaccards coefficient with average linkage clustering) produced very similar results.

Community analyses at Coomonderry Swamp

The percentage frequency of occurrence in quadrats was calculated for all species within each of the 36 community transect units identified by TWINSPAN. Cluster analysis was performed on the resulting matrix to relate the floristics of the whole wetland (cf. Keith & Myerscough 1993). The Bray-Curtis measure of dissimilarity and flexible UPGMA (unweighted pair group arithmetic averaging) agglomerative clustering technique with $\beta = -0.1$ (Belbin 1987) was chosen to analyse these data. Alternative methods again produced similar results.

Ordination using hybrid multi-dimensional scaling (HMDS) (Belbin 1987) was carried out on the Bray-Curtis association matrix derived from the initial TWINSPAN analysis of transects. Ordinations were performed in three and four dimensions with a 0.8 cut (Belbin 1987).

Following cluster analysis and ordination, hypotheses were generated regarding the relationship between floristics and soil-water characteristics, structural characteristics of the vegetation and disturbance factors. Each community transect unit was characterized by calculating values (*a posteriori*) for measures which could be indicative of each of these factors. These measures were means for: (i) relative elevation (cm); (ii) soils ranked: 1 - peat, 2 - humic, and 3 - sandy; and (iii) species richness at 10 m^2 scale (five quadrat interval). Other measures for each vegetation unit were: (i) vegetation height calculated from the formula: $[\Sigma(nh)]+q/[\Sigma n]+q$ (where 'n' = the number of quadrats with ≥ 10% cover for a given species, 'h' = ranked height class for each of these species, and 'q' is the number of quadrats having no species with ≥ 10% cover); (ii) proportion of introduced taxa and (iii) proportion of woody perennials together with longer-lived, non-woody species whose populations exhibited constancy (Putman 1994) over three years of seasonal and hydrological flux.

Pairwise correlations between each variable and each ordination vector were calculated using Pearson correlation coefficients. The significance of correlations was tested with *t* - tests with the level of significance reduced to $P = 0.001$ by the Bonferroni procedure to compensate for the number of correlations.

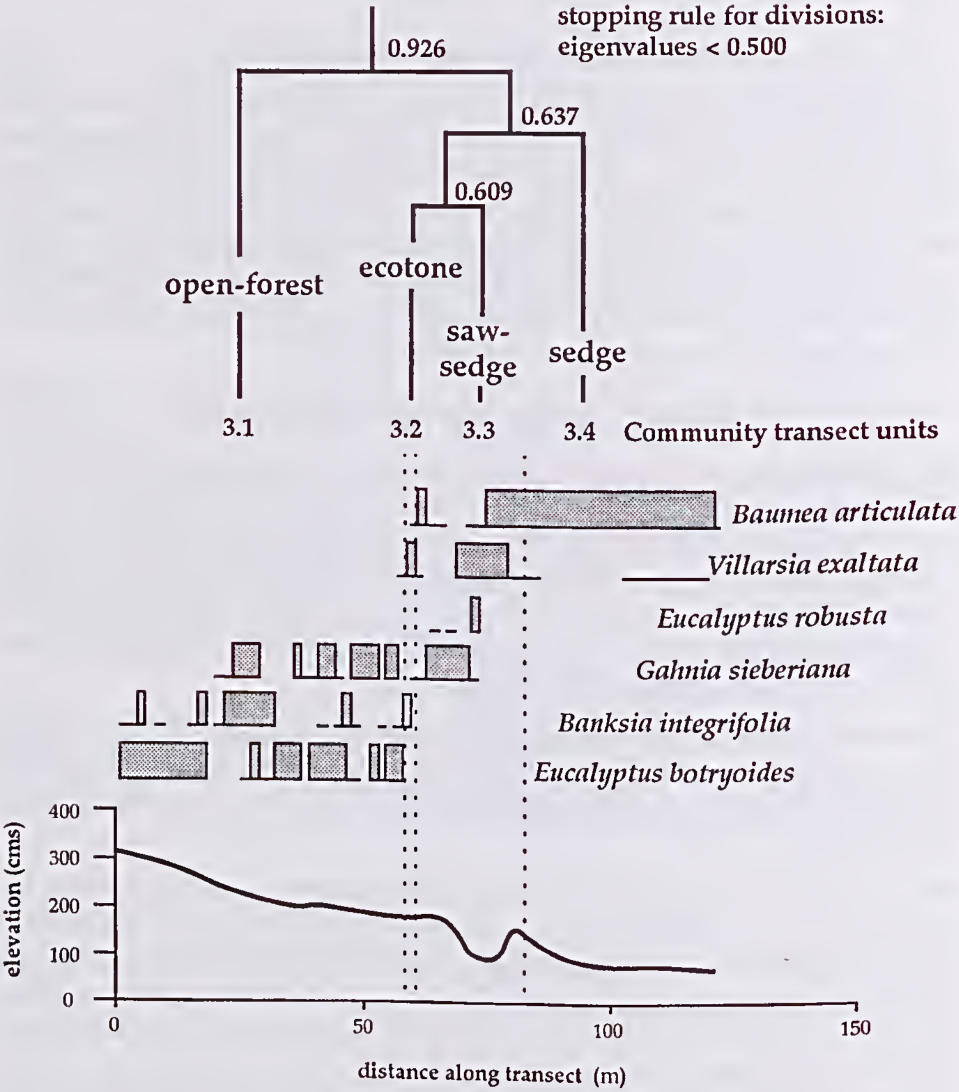

Fig. 2. Community transect divisions derived from TWINSPAN analysis of species composition in quadrats along Transect 3 at Coomonderry Swamp. Direct gradient analysis shows the distribution and abundance of some key indigenous species. Lines show presence of named species. Shaded bars show % cover ≥ ten. Transect divisions are numbered consecutively down the transect.

Comparisons with other wetlands

Community transect units were also identified along transects at other wetlands (Table 1) by using TWINSPAN. All community transect units (including those from Coomonderry Swamp) were compared by forming a percentage frequency occurrence matrix and then applying the clustering and ordination techniques in the way previously described. Once again correlations between vectors (three to five) and floristic and soil-water characteristics were calculated. Additional variables included two soil ranks: 4 - sand and 5 - laterite, pH and salinity. Correlations were not carried out for salinity and pH with community transect units above water level. The significance of correlations was tested with t - tests, with the level of significance reduced to $P = 0.001$ by the Bonferroni procedure, to compensate for the number of correlations performed. Soil-water and structural attributes of each community type derived from the clustering procedure were compared using single-factor ANOVA, with multiple comparison of means performed with Fisher PLSD tests. None of the appropriate transformations removed heterogeneity among variances and so ANOVAS were performed on the untransformed data.

Results

Community analyses at Coomonderry Swamp

Over 200 plant species were recorded within Coomonderry Swamp and along its margins (Appendix 1) and eleven communities were recognized (Fig. 3). For purposes of comparison with other wetlands, these were further reduced to seven: with fresh wet meadow, floating mat and ephemeral meadow being considered 'local variants' of wet meadow; *Melaleuca* and *Melaleuca–Casuarina*, local variants of *Melaleuca*; and *Marsilea* and *Utricularia–Eleocharis* complexes, local variants of deep freshwater communities. As indicated, arrangements of communities varied little among alternative clustering procedures. Discrepancies arose in the classification of 'mixed' communities, for example, disturbed and open *Melaleuca* scrub which contained understories dominated by short-lived herb and grass species. Such units could be grouped with other *Melaleuca* communities, or alternatively, with wet meadow communities.

The diversity of communities found at Coomonderry Swamp reflects the complexity of factors influencing floristics. The four dimensional ordination resulted in a 24% reduction in stress (to 0.1307) over three vector analysis, and better differentiated correlated variables, albeit with a corresponding increase in 'noise' (Table 2). The trend in negative to positive scores for vector 1 corresponded to an increase in elevation and decrease in organic content of soils. Vector 2 correlated strongly with structural components of the vegetation, the negative to positive sequence of vector values matching a general increase in canopy height with an associated decrease in proportions of introduced taxa. Vector 3 suggested the influence of human disturbance at Coomonderry Swamp (and disturbance and stress related to inundation changes lower on the elevation gradient). The negative to positive sequence of vector scores in this instance generally matched an increase in the proportion of introduced species and related decrease in woody perennials and longer-lived non-woody perennials. Vector 4 indicated the influence of soil characteristics with the trend from negative to positive vector scores correlated with a decrease in humic content of soil. More soil analysis is needed to define those characteristics that influence floristics in this wetland (cf. Keith & Myerscough 1993).

The categories of factors delineated by ordination: disturbance, structure and elevation; are superimposed on the dendrogram (Fig. 3) to indicate their relative importance to early divisions of the cluster analysis.

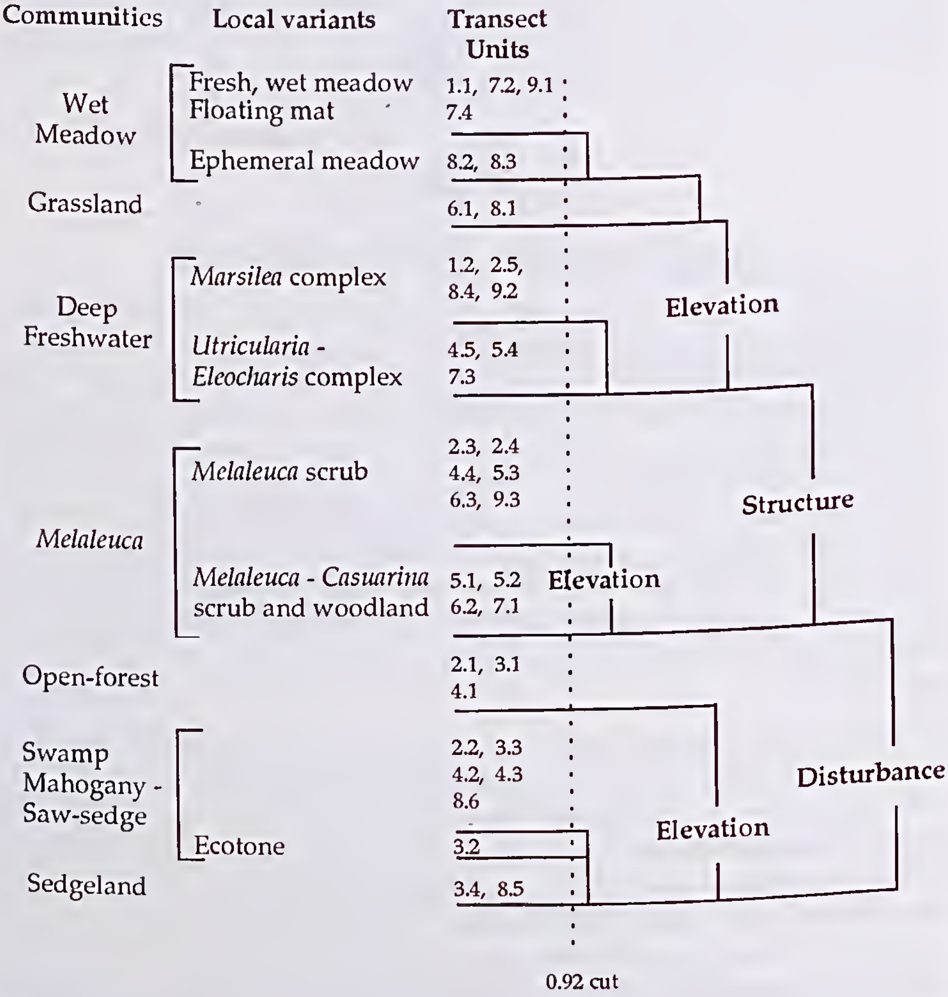

Fig. 3. Dendrogram derived from cluster analysis of all community transect units at Coomonderry Swamp. Correlations with ordination vectors indicated the importance of disturbance, structure and elevation in determining early divisions of the cluster analysis.

Table 2 Pearson correlation coefficients for four vector ordination of community floristics at Coomondery Swamp with elevation, soil and variables indicative of vegetation structure and disturbance.

	Vector 1	Vector 2	Vector 3	Vector 4	Veg. height	Elev.	Introd.	Peren.	Species rich.
Veg. height	0.049	**0.809***	-0.137	0.453					
Elev.	**0.581***	0.260	0.366	0.379	0.291				
Introd.	-0.292	**-0.640***	**0.663***	-0.177	**-0.599***	-0.057			
Peren.	0.249	0.495	**-0.539***	0.395	0.522	0.075	**-0.721***		
Species richness	0.353	0.127	0.448	-0.084	-0.031	0.316	0.025	-0.266	
Soil index	**0.54S***	0.284	0.269	**0.610***	0.386	**0.763***	-0.077	0.258	0.185

Critical value: $P = 0.001$. *$P < 0.001$. See text for description of variables. 'n' = 36 community transect units.

Characteristics of communities at Coomonderry Swamp

Five communities at Coomonderry Swamp were found along margins subject to greatest anthropogenic disturbance and consequently high proportions of ruderal species predominated.

Fresh, wet meadow Areas of wet meadow occurred principally on the southern and south-western margins of the wetland where heavier, peaty soils were subject to frequent fluctuations in inundation (de Jong 1997). These areas have been consistently grazed in the past and cattle still enter the wet meadow during periods of greatest draw-down. Wet meadow is one of the more species-rich communities in the wetland, with more than 90 species recorded in proximity to Transect 1 alone (Fig. 1). Wet meadow at Coomonderry Swamp was dominated by species of Cyperaceae, Juncaceae and Poaceae. Key species included *Hydrocotyle peduncularis, Triglochin procerum, Isolepis prolifera, Juncus polyanthemus, Pseudoraphis paradoxa, Paspalum distichum* and *Persicaria decipiens. Cotula coronopifolia* and *Triglochin striatum*, species commonly associated with saline environments, periodically occurred.

Floating mat An unusual community transect unit clustered as wet meadow was a floating mat of vegetation of ≥ 50 cm thickness within a stand of *Melaleuca ericifolia* in water > 1 m depth.

Ephemeral meadow During periods of severe draw-down, extensive blooms of ephemeral and opportunistic species soon covered mud in areas of previously open water. Dominant species along the upper margins, trampled by cattle, included *Cynodon dactylon, Hydrocotyle peduncularis, Axonopus affinus, Paspalum dilatatum* and *Trifolium repens*. At lower elevations *Centipeda minima, Hydrocotyle bonariensis, Myriophyllum simulans* and *Juncus polyanthemus* were common — the latter two species probably present prior to draw-down.

Grassland Grazed areas above much of the western, southern and northern margins of Coomonderry Swamp were predominantly covered with *Pennisetum clandestinum.* Other species were *Axonopus affinus, Trifolium repens, Cynodon dactylon, Hypochaeris radicata* and *Carex appressa.*

***Marsilea* complex** Deep freshwater communities are the flooded counterparts of ephemeral communities. *Marsilea mutica* predominated beyond wet meadow, over the summer months, and in water generally less than 60 cm. Other key components included *Isolepis prolifera, Juncus polyanthemus, Triglochin procerum, Utricularia australis, Eleocharis sphacelata, Myriophyllum simulans, Pseudoraphis paradoxa* and *Paspalum distichum.*

***Utricularia–Eleocharis* complex** Deep water areas of the swamp, not dominated by *Melaleuca* spp. or *Baumea articulata* (but often occurring with these), principally supported *Utricularia* spp. interspersed with tall clumps of *Eleocharis sphacelata* and *Typha orientalis.* Other floating species included *Nymphaea* spp., *Potomogeton* spp., and *Persicaria* spp.

The aforementioned communities illustrate the dynamics often associated with systems subjected to frequent disturbance. Sedgelands however, and the undisturbed, wooded, eastern margin have remained robust in the face of these short term environmental and seasonal fluctuations (de Jong 1997). Cluster analysis delineated five resilient communities.

***Melaleuca* scrub** *Melaleuca ericifolia* is perhaps the most pervasive species in this wetland, occurring as thickets throughout the sedgland and almost continuously along the 5 km length of the undisturbed margin. Remnant pockets on the western margin suggest extensive clearing. Co-occurring species varied depending on water depth and disturbance within each *Melaleuca* community. *Azolla filiculoides, Spirodela punctata* and *Persicaria praetermissa* were common understory species in standing water.

***Melaleuca–Casuarina* scrub and woodland** *Casuarina glauca* was a dominant or co-dominant woody species, often occurring above stands of *Melaleuca ericifolia* along the elevation gradient. *Carex appressa, Gahnia sieberiana, Entolasia marginata* and *Viola hederacea* were common understory species of grazed, dryer ground at the northern end of the wetland. *Isolepis inundata, Isolepis prolifera, Eleocharis acuta* and *Persicaria praetermissa* were common members of *Melaleuca–Casuarina* communities at slightly lower elevations. *Melaleuca linariifolia* was a secondary wooded component of some *Melaleuca* and *Melaleuca–Casuarina* communities.

Sedgeland The extensive central body of Coomonderry Swamp is covered by sedge, principally *Baumea articulata,* but also *Baumea arthrophylla.* Within this continuous 2 m tall stratum, *Villarsia reniformis* was found with some of the typically open water species previously described. Isolated stands of *Typha orientalis, Phragmites australis* and *Eleocharis sphacelata* were scattered throughout the sedgeland. *Baumea juncea* with *Villarsia exaltata* became increasingly common with more shallow inundation or on moist soil.

Swamp Mahogany–Saw-sedge The transition between sedgeland and forest is typified by open *Eucalyptus robusta* (Swamp Mahogany) woodland with isolated *Casuarina glauca* and *Melaleuca* spp., an often very open shrub/sedge stratum of *Gahnia sieberiana* (Saw-sedge), *Leptospermum juniperinum* and *Baumea* spp., and a dense grass/herb substratum dominated by *Hemarthria uncinata, Villarsia exaltata, Lobelia alata* and *Goodenia paniculata.*

Open-forest *Eucalyptus pilularis* open-forest, on sandier soils to the north, and *Eucalyptus botryoides* open-forest on more humic soils to the south, were clustered together in this analysis on the basis of a strong similarity in understory components. Open-forest is a relatively species-rich community at Coomonderry Swamp. The usually dense small tree and shrub strata were composed of a broad range of species including *Glochidion ferdinandi, Elaeocarpus reticulatus, Banksia serrata, Banksia integrifolia, Breynia oblongifolia, Myoporum* spp., *Acacia* spp. and *Monotoca elliptica.* Understorey species included *Gahnia sieberiana, Entolasia* spp., *Oplismenus aemulus, Dianella caerulea, Pteridium esculentum* and *Lomandra longifolia.* Pockets of rainforest occurred throughout the open-forest and several species of vines (e.g. *Parsonia straminea, Smilax glyciphylla, Marsdenia rostrata* and *Cissus hypoglauca*) were a strong constituent of both the rainforest and open-forest vegetation.

Comparisons with other wetlands

In addition to the 36 community transect units from Coomonderry Swamp, TWINSPAN analysis identified a further 46 from transects at other sites. Cluster analysis, based on the total 82 units × species (% frequency occurrence in quadrats) matrix, defined some communities and several local variants not encountered at Coomonderry Swamp (Fig. 4). These included dry meadow, saltmarsh, mangrove and deep estuarine communities. Swamp Mahogany–saw-sedge, sedgeland and wet meadow communities of the type found at Coomonderry Swamp did not occur, or were poorly represented at these other sites.

HMDS ordination in four vectors was selected as best for differentiating floristics over the broad range of wetland sites (Table 3), although some variables themselves were strongly correlated and were thus poorly separated in the ordination. The factors correlated significantly were: salinity and introduced taxa (vector 1), vegetation height, species richness and pH (vector 2), disturbance (i.e. introduced taxa and the proportion of perennial species — vector 3) and a range of components related to the elevation gradient (elevation, vegetation height, soil and salinity — vector 4). Correlations should be treated with additional caution as the stress value in four dimensions was high (0.1843). However five vector ordination did not improve differentiation of variables although stress was reduced by 17% to 0.1533.

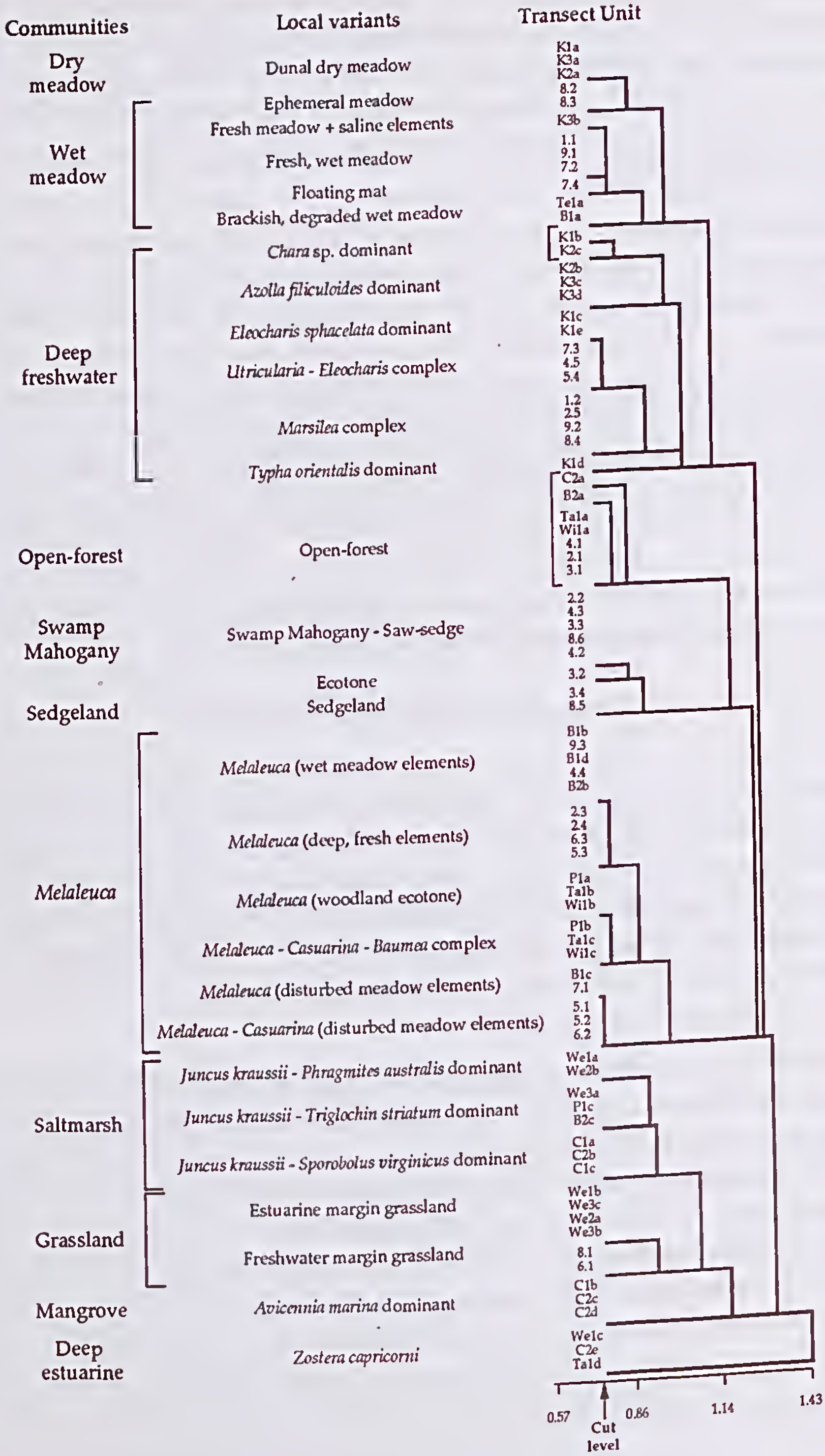
Communities
Local variants
Transect Unit
Dry meadow
Dunal dry meadow
K1a
K3a
K2a
8.2
8.3
Wet meadow
Ephemeral meadow
Fresh meadow + saline elements
K3b
Fresh, wet meadow
1.1
9.1
7.2
Floating mat
7.4
Brackish, degraded wet meadow
Te1a
B1a
Deep freshwater
Chara sp. dominant
K1b
K2c
Azolla filiculoides dominant
K2b
K3c
K3d
Eleocharis sphacelata dominant
K1c
K1e
Utricularia - *Eleocharis* complex
7.3
4.5
5.4
Marsilea complex
1.2
2.5
9.2
8.4
Typha orientalis dominant
K1d
Open-forest
Open-forest
C2a
B2a
Ta1a
Wi1a
4.1
2.1
3.1
Swamp Mahogany
Swamp Mahogany - Saw-sedge
2.2
4.3
3.3
8.6
4.2
Ecotone
3.2
Sedgeland
Sedgeland
3.4
8.5
Melaleuca
Melaleuca (wet meadow elements)
B1b
9.3
B1d
4.4
B2b
Melaleuca (deep, fresh elements)
2.3
2.4
6.3
5.3
Melaleuca (woodland ecotone)
P1a
Ta1b
Wi1b
Melaleuca - *Casuarina* - *Baumea* complex
P1b
Ta1c
Wi1c
Melaleuca (disturbed meadow elements)
B1c
7.1
Melaleuca - *Casuarina* (disturbed meadow elements)
5.1
5.2
6.2
Saltmarsh
Juncus kraussii - *Phragmites australis* dominant
We1a
We2b
Juncus kraussii - *Triglochin striatum* dominant
We3a
P1c
B2c
Juncus kraussii - *Sporobolus virginicus* dominant
C1a
C2b
C1c
Grassland
Estuarine margin grassland
We1b
We3c
We2a
We3b
Freshwater margin grassland
8.1
6.1
Mangrove
Avicennia marina dominant
C1b
C2c
C2d
Deep estuarine
Zostera capricorni
We1c
C2e
Ta1d
0.57
Cut level
0.86
1.14
1.43

Fig. 4. Dendrogram derived from cluster analysis of all community transect units encountered at nine South Coast wetlands. Association values are shown along the bottom. Community names for Coomonderry Swamp are abbreviated as shown in Fig. 2. Abbreviations for other wetlands are initials: Killalea, Terrara, Brundee, Crooked, Tabourie, Willinga, Pattimores and Werri; followed by transect number and section of transect ('a' uppermost) i.e. We3c is the 3rd community down the elevation gradient along Transect 3 at Werri Lagoon.

Table 3 Pearson correlation coefficients for four vector ordination of community floristics at nine South Coast wetlands with variables indicative of vegetation structure, disturbance and soil-water characteristics.

	Vector 1	**Vector 2**	**Vector 3**	**Vector 4**	**Veg ht.**	**Elev.**	**Introd.**	**Peren.**	**Spec. rich.**	**Soil index**	**pH**
Veg. ht.	0.006	**-0.494***	-0.348	**-0.494***							
Elev.	0.130	-0.109	-0.089	**-0.391***	0.276						
Introd.	**0.363***	0.203	**0.701***	0.218	**-0.401***	0.115					
Peren.	-0.015	-0.236	**-0.545***	-0.249	**0.530***	-0.049	**-0.601***				
Spec. rich.	0.163	**-0.367***	-0.006	-0.142	0.156	**0.494***	0.103	-0.168			
Soil index	-0.087	-0.109	-0.125	**-0.441***	0.306	**0.638***	0.038	0.126	**0.415***		
pH	-0.388	**0.549***	0.120	-0.438	-0.296	-0.279	-0.246	-0.182	-0.314	-0.066	
Sal.	**-0.522***	0.456	0.210	**-0.585***	-0.180	-0.146	-0.294	-0.159	-0.321	-0.229	**0.842***

Critical value: $P = 0.001$. $^*P < 0.001$. See text for description of variables. 'n' = 82 community transect units except for salinity and pH where 'n' = 49.

Characteristics of communities at other wetlands

The floristics and structure of plant communities could be related to the particular sets of conditions operating in each wetland surveyed (Tables 4 & 5). In the following descriptions relationships between other wetlands surveyed, and communities and key species of Coomonderry Swamp are emphasised.

Wet meadow communities Ephemeral and wet meadow communities at Coomonderry Swamp were clustered with the brackish wet meadow communities of Brundee, Terrara and Killalea swamps. All these communities were similar in structure, disturbance regime and species richness, and shared a large common pool of short-lived, herbaceous species and Cyperaceae. However the abundance of *Bacopa monniera, Aster subulatus, Hydrocotyle bonariensis and Crassula peduncularis* at Killalea wetland indicated the distinctive saline and dunal influence at this site, while the importance of *Cotula coronopifolia, Aster subulatus* and *Triglochin striatum* at Brundee and Terrara was indicative of the brackish inundations experienced by these two wetlands.

Deep, freshwater communities Killalea Swamp was the only other freshwater wetland surveyed and many significant components of Coomonderry Swamp were also found to be important here. These included, *Eleocharis sphacelata, Baumea articulata, Schoenoplectus validus, Typha orientalis, Ludwigia peploides, Azolla filiculoides, Spirodela punctata* and *Myriophyllum simulans*. Notable absences were *Marsilea mutica* and *Melaleuca* spp., while *Chara* sp. was the dominant open water plant.

Table 4 **Characteristics of plant communities**

Community	Soils	Occurrence at sites	Structure	Main species
Dry meadow	Sand. Organic content increasing at wetland margin.	Degraded sand dunes adjacent to the eastern margin of Killalea Swamp.	Herb-field. Grassland.	*Hydrocotyle bonariensis* *Cynodon dactylon* *Pennisetum clandestinum* *Isolepis nodosa*
Wet meadow	Peat.	Periodically submerged, unwooded margins of Killalea Swamp and Coomonderry Swamp. Terrara Swamp and Brundee Swamp flats.	Herb-field.	*Isolepis prolifera* *Juncus polyanthemus* *Persicaria decipiens* *Juncus prismatocarpus* *Paspalum distichum* *Senecio madagascariensis*
Deep freshwater	Peat.	Killalea Swamp, Coomonderry Swamp.	Submerged, floating and emergent species of open water in sedgeland, rushland and reedland.	*Eleocharis sphacelata* *Azolla filiculoides* *Marsilea mutica* *Typha orientalis* *Utricularia australis* *Baumea articulata* *Ludwigia peploides* *Chara* sp.
Open-forest	Sandy soils with increasing humic content approaching wetland margin. Lateritic at Brundee.	Higher, dry ground above Crooked, Coomonderry, Brundee, Pattimores, Tabourie and Willinga wetlands.	Open-forest with upper, mid (shrub) and low (herb) layers. Closed-forest (rainforest) in patches at Coomonderry Swamp.	*Eucalyptus botryoides* *Eucalyptus pilularis* *Acacia longifolia* *Breynia oblongifolia* *Pterideum esculentum* *Entolasia* spp. *Lomandra longifolia* *Hibbertia scandens* *Kennedia rubicunda* *Imperata cylindrica*
Swamp mahogany –saw-sedge	Humic to peaty soils.	Eastern margin of Coomonderry Swamp - rarely inundated.	Open-woodland.	*Eucalyptus robusta* *Casuarina glauca* *Gahnia sieberiana* *Hemarthria uncinata* *Villarsia exaltata* *Leptospermum juniperinum*
Sedgeland	Peat.	Central body of Coomonderry Swamp.	Open sedgeland, sedgeland and reedland.	*Baumea articulata* *Baumea arthrophylla* *Villarsia reniformis* *Villarsia exaltata*
Melaleuca	Humic to peaty soils.	Coomonderry and Brundee Swamps. Upper tidal to dry margins of Pattimores, Tabourie and Willinga wetlands.	Scrub and woodland with herb understory.	*Melaleuca ericifolia* *Casuarina glauca* *Baumea juncea* *Persicaria praetermissa* *Viola hederacea* *Entolasia stricta*

Table 4 Continued

Saltmarsh	Saline, organic, sandy or silty loams.	Tidal margins of Werri Lagoon, Crooked River and Pattimores Lagoon. Brundee Swamp flats.	Reedland, open-herb-field and open-grassland.	*Juncus kraussii* *Phragmites australis* *Sporobolus virginicus* *Triglochin striatum*
Grassland	Humic, silty or sandy loams.	Grazed margins at Werri Lagoon and Coomonderry Swamp.	Grassland.	*Pennisetum clandestinum* *Stenotaphrum secundatum* *Casuarina glauca*
Mangrove	Saline, organic loams.	Tidal areas of Crooked River.	Low, open scrub, open herb-field.	*Avicennia marina* *Sarcocornia quinqueflora*
Deep estuarine	Saline, organic loams.	Werri, Crooked and Tabourie estuaries.	Attached, floating species.	*Zostera capricorni*

The various attributes distinguishing communities are shown in Table 5. Main species are ranked in a general order of importance in terms of distribution and abundance on transects within communities.

Grassland Areas of grazed paddock adjoined some parts of Killalea, Crooked River, Brundee and Terrara wetlands, but were only included in transect surveys at Werri Lagoon. At this site the dominant grass species was Kikuyu (*Pennisetum clandestinum*) although *Stenotaphrum secundatum* was also prevalent. Saline elements were interspersed throughout the grassland, particularly in the wettest areas. These included *Juncus kraussii, Leptinella longipes, Tetragonia tetragonoides* and remnant *Casuarina glauca*.

***Melaleuca* communities** *Melaleuca* scrub at the brackish wetland, Brundee, was similar to that described at Coomonderry Swamp. At both sites, this species continued into standing water forming a dense stratum often taller than 3 m. At Brundee *Melaleuca styphelioides* is a co-dominant woody species in addition to *Casuarina glauca*. Only a few *Melaleuca styphelioides* trees occur at Coomonderry Swamp. Understory species in wetter stands at Brundee were also similar to those found at Coomonderry Swamp despite salinities ranging up to 6 ppt. On drier margins there were numerous affinities with the open-forest vegetation of Coomonderry Swamp, even though parent soils here are lateritic.

Melaleuca ericifolia was the dominant transition species of all relatively undisturbed estuarine wetlands surveyed. As at Brundee, this species remained a significant component on humic soils, perhaps further into woodland than encountered at Coomonderry Swamp. *Melaleuca ericifolia* communities adjoining estuaries did not progress beyond the deeper water margins suggesting an intolerance to continuous saline inundation. The estuarine *Melaleuca ericifolia* communities surveyed formed a

Table 5. Attributes of communities encountered at nine coastal wetlands in southern NSW.

	Dry meadow	**Wet meadow**	**Deep fresh**	**Open-forest**	**Swamp mahogany**	**Sedge**	***Melaleuca***	**Salt-marsh**	**Grassland**	**Mangrove**	**Deep estuary**	***P***
Veg. height	1.18 (0.18) a	1.21 (0.11) a	1.48 (0.10) a	2.44 (0.21) c	2.28 (0.14) bc	1.57 (0.11) ab	2.32 (0.10) c	1.49 (0.13) a	1.61 (0.32) a	1.36 (0.28) a	1.00 (0.00) a	*
Elevation	126 (73) d	7 (4) bc	-47 (11) a	195 (60) d	31 (13) bc	-6 (6) abc	2 (7) bc	-11 (7) abc	41 (16) c	-47 (2) ab	-76 (30) a	*
Proportion introd. taxa	0.40 (0.03) c	0.37 (0.04) c	0.11 (0.04 ab	0.02 (0.02) a	0.01 (0.01) a	0.00 (0.00) ab	0.09 (0.02) ab	0.16 (0.06) b	0.65 (0.10) d	0.00 (0.00) ab	0.00 (0.00) ab	*
Proportion perenn. taxa	0.12 (0.03) ab	0.14 (0.03) ab	0.39 (0.08) c	0.43 (0.02) c	0.48 (0.04) c	0.54 (0.04) c	0.41 (0.05) c	0.28 (0.04) bc	0.12 (0.04) ab	0.31 (0.03) ac	0.00 (0.00) a	*
Species richness	9.5 (1.0) bcd	13.6 (1.6) ab	5.1 (0.8) cf	15.1 (1.4) a	9.2 (1.2) d	5.3 (0.7) cdf	8.3 (1.0) d	5.6 (0.8) cdf	6.8 (1.5) cde	2.6 (0.1) ef	1.0 (0.0) f	*
Soil index	3.0 (0.6) a	1.3 (0.2) cd	1.0 (0.0) d	3.3 (0.3) a	2.0 (0.0) b	1.0 (0.0) d	1.7 (0.1) bc	1.4 (0.2) cd	2.0 (0.0) b	1.0 (0.0) d	1.0 (0.0) d	*
pH	-	5.9 (0.1) a	6.0 (0.1) a	-	-	5.9 (0.1) a	5.9 (0.2) a	6.6 (0.2) b	-	7.0 (0.0) b	7.0 (0.0) b	*
Salinity	-	0.7 (0.6) ab	0.1 (0.0) a	-	-	0.0 (0.0) ab	7.6 (4.0) b	19.2 (4.1) c	-	31.2 (0.8) c	28.3 (8.0) c	*
n	3	9 (5)	15	7	6	2	20 (13)	8	6	3	3	

Data are means, with standard errors in parentheses, for 'n' replicates of community transect units clustered together within each community (Fig. 4). Salinity and pH calculated for inundated community transect units only ('n' in parentheses). Means in each row designated 'a - f' (Fisher PLSD - ANOVA) are not significantly different at P= 0.05. Level of significance is * $P \leq 0.0001$. Elevations are in centimetres and salinities are in ppt. Other variables are described in the text.

dense 2 m high closed canopy. On drier, sandier soils *Melaleuca ericifolia* commonly occurred with *Eucalyptus botryoides, Acacia longifolia* and *Entolasia stricta.* On wetter, more humic soils *Leptospermum juniperinum, Leptospermum polygalifolium, Centella asiatica, Casuarina glauca, Baumea juncea, Cassytha pubescens, Selaginella uliginosa* and *Hemarthria uncinata* were important components. On peaty, wet soils *Baumea juncea, Phragmites australis, Juncus kraussii* and *Samolus repens* became increasingly more prevalent. Species richness decreased down the elevation gradient within these communities.

Open-forest communities *Eucalyptus botryoides* was the dominant canopy species on sandy soils at Lake Tabourie, Lake Willinga, Pattimores Lagoon and Crooked River. On lateritic soils at Brundee *Eucalyptus pilularis* was the dominant tall woody species. Mid-story and under-story strata were very similar in all these communities, although a number of species at Brundee—*Acacia falcata, Daviesia ulicifolia, Hibbertia diffusa* and *Eucalyptus ?imitans*—were not found elsewhere.

Dunal, dry meadow communities Disturbed, dryer communities adjacent to the eastern margins of Killalea wetland, supported a number of taxa commonly found on sand dunes. The dominant species found were *Hydrocotyle bonariensis, Cynodon dactylon, Pennisetum clandestinum, Isolepis nodosa, Zoysia macrantha* and *Spinifex sericens.* Some typical wet meadow species from quadrats on the waterline were also clustered in these communities.

Saltmarsh communities There was considerable heterogeneity in saltmarsh within and between sites surveyed. *Juncus kraussii, Triglochin striatum* and *Phragmites australis,* were characteristic of grazed saltmarsh at Werri Lagoon and Brundee. *Sporobolus virginicus, Juncus kraussii* and *Phragmites australis* were important components of less disturbed margins. Quadrats containing saltmarsh species were classified with *Melaleuca ericifolia* where the latter made a sharp boundary with open water, while at other sites, saltmarsh formed an understory component of mangrove communities. Open saltmarsh flats at Crooked River were variously dominated by *Suaeda australis, Juncus kraussii* and *Sporobolus virginicus,* usually in shallower water, and *Sarcocornia quinqueflora* with *Avicennia marina* in deeper water.

Mangrove–saltmarsh communities *Avicennia marina* was only encountered at Crooked River where it occurred with *Sarcocornia quinqueflora, Suaeda australis* and *Sporobolus virginicus.*

Deep estuarine communities Transects at lagoonal sites were terminated in deep water where *Zostera capricorni* predominated.

Discussion

Plant communities at Coomonderry Swamp

A significant ecological feature of Coomonderry Swamp is its diversity of plant communities and the associated diversity of habitat available to avifauna (Blachford & Reeks 1976; Lawler & Porter 1990). Under Goodrick's (1970) general classification, six out of nine categories of freshwater wetland are represented at Coomonderry Swamp. Three of these — fresh meadow, seasonal fresh swamp and open fresh water — have been considered to be of high value to birds (Blachford & Reeks 1976). The extent and state of preservation of the sedgeland–swamp mahogany–woodland–dunal transition is of great value since similar stands are poorly represented south of Sydney. Floating mats are an unusual occurrence (but see Hill & Webb 1982; Mitch & Gosselink 1993).

Coomonderry Swamp is a geographically isolated example of a freshwater, dunal wetland and consequently it has major importance as a refuge for some plant species such as *Eucalyptus robusta, Villarsia reniformis, Lilaeopsis polyantha,* regionally uncommon members of the Juncaceae, and uncommon ephemerals such as *Cyperus odoratus* (Appendix 1).

While most plant communities (Fig. 3) defined in this analysis have remained structurally consistent over time (i.e. 50 years–aerial photographs, see de Jong 1997), wet meadow, ephemeral and open water complexes were highly dynamic. However, ephemeral and open water communities reoccurred in a consistent cyclic pattern while temporal monitoring over 3.5 years suggested that a finer resolution of wet meadow was not warranted (de Jong 1997).

The diversity of plant communities at Coomonderry Swamp appeared to be the consequence of a complex interaction of factors. Rates of change in the inundation regime, changes in soil characteristics and water status along the elevation gradient, and levels of anthropogenic disturbance varied between different margins of the wetland. In general terms, a toposequence: grassland–wet meadow–open water–sedgeland could be recognized on much of the northern, western and southern farmed margins. A 'hybrid' toposequence: grassland–(rarely Swamp Mahogany)–*Melaleuca* or *Melaleuca/Casuarina*–open water–sedgeland was found where grazed land abutted steeper margins. The toposequence: open-forest (sometimes littoral rainforest)–Swamp Mahogany woodland–*Melaleuca*–sedgeland was developed on the eastern undisturbed fringe.

Comparison of Coomonderry Swamp with wetlands of the Jervis Bay region

Wetlands associated with Jervis Bay were purposely omitted from the present study because of time constraints and because they had received more attention than other South Coast wetlands (Adam & Hutchings 1987; Clarke 1993; Clarke et al. 1995; Mills 1995). Mills (1995) provided a comprehensive overview of the natural vegetation of the Jervis Bay area in which he described a number of communities closely affiliated with those found at Coomonderry Swamp. Floristically and structurally, both *Eucalyptus botryoides* and *Eucalyptus pilularis* open-forest communities at Jervis Bay are similar to those found at Coomonderry Swamp. Mills (1995) commented on the usually distinct boundary between the two, and this is also a feature of their occurrence on sand above Coomonderry Swamp. At Jervis Bay littoral rainforest sometimes forms part of this coastal lowland complex. Equivalents of several other coastal communities described by Mills (1995) are found within Seven Mile Beach National Park, immediately east of Coomonderry Swamp, but were not described in the present study.

Casuarina glauca and *Melaleuca ericifolia* communities at Jervis Bay are most often associated with estuarine margins (Mills 1995). Many components of the *Melaleuca ericifolia* substrata are similar to those found at Coomonderry Swamp e.g. *Hemarthria uncinata* and *Entolasia stricta.* However *Casuarina glauca* communities at Jervis Bay indicate the saline influence, with species such as *Samolus repens, Juncus kraussii* and *Apium prostratum* (Mills 1995). Sedgelands at Jervis Bay occur in depressions on sandstone soils (Mills 1995). These communities are floristically different to sedgeland at Coomonderry Swamp and are considered by Mills (1995) to resemble those described for upland swamps. *Eucalyptus robusta* forest–woodland is associated with floodplains and fresh swamps at Jervis Bay (Mills 1995) and is similar to the freshwater–open-forest transition at Coomonderry Swamp, though much less extensive (Braithwaite et al. 1995).

Comparison of Coomonderry Swamp with tableland and upland swamps

The toposequence described for the undisturbed margin of Coomonderry Swamp structurally equates, to some degree, with the *Eucalyptus* woodland–*Banksia* thicket–Restioid/Cyperoid heath–tea-tree toposequences described by Keith & Myerscough (1993) and noted by Stricker & Wall (1995) for upland swamps on tablelands south of Sydney, NSW. This is particularly so where *Melaleuca ericifolia* thickets are found interpersed in deeper areas of sedgeland at Coomonderry Swamp analogous to tea-tree thickets occupying the most waterlogged parts of upland swamps. Keith & Myerscough (1993) in their report also recognized general structural similarities with a related toposequence described by Myerscough and Carolin (1986) for coastal dune fields 200 km north of Sydney. Keith & Myerscough (1993) noted other floristic analogs, all related to a gradient in soil moisture, organic matter and nutrients, for a diversity of temperate heathlands along the eastern coast of Australia.

Despite these structural similarities, floristic composition and species richness at Coomonderry Swamp contrasted greatly with upland swamps. All communities surveyed for this report were much less species rich, and the only affinities in floristics occurred where undisturbed *Melaleuca* communities at Coomonderry Swamp shared some dominants (e.g. *Leptospermum juniperinum* and *Gahnia sieberiana*) with *Melaleuca* thickets of upland swamps. Upland swamps of the Boyd Plateau, Central Tablelands (Kodela et al. 1996) are even more floristically distinct.

Greater similarities in species composition were found between Coomonderry Swamp and some freshwater lagoons and reed swamps of 'the coastal division' described by Stricker & Wall (1995) and Ryan et al. (1996), although wetlands described by these workers are located further from the coast (>50 km), at intermediate elevations (100–500 m above sea level), and at least 100 km north of Coomonderry Swamp.

Comparison of Coomonderry Swamp with coastal wetlands of the Sydney region and central coast of NSW

As previously indicated, freshwater dunal wetlands such as Coomonderry Swamp are more commonly found north of Sydney. Structural and floral characteristics of the dune–woodland–fringe forest–swamp transition at Coomonderry Swamp and of the

Eurunderee system (Myerscough & Carolin 1986) are very similar. Dry sclerophyll forest communities described by Myerscough & Carolin (1986) have most dominant components in common with the *Eucalyptus pilularis* open-forest of drier, sandy ground above Coomonderry Swamp (Table 4), although species associated with heath ecotones at Eurunderee are not found at Coomonderry Swamp. Many dry sclerophyll members described by Myerscough & Carolin (1986) were also noted in the substrata of *Eucalyptus botryoides* open-forest at Coomonderry Swamp. Here also, a number of species listed by Myerscough & Carolin (1986) for vine thicket, headland thicket and rainforest occurred, particularly on more humic soils, and where littoral rainforest is developed within the woodland (see Mills & Jakeman 1995). Although not surveyed for this report, foredune and hinddune communities from both localities had much in common (de Jong pers. obs.)

More significant differences were apparent when communities of the swamp and immediate margins were compared. *Lepironia articulata* and *Melaleuca quinquenervia,* two species not naturally occurring on the south coast of NSW, dictate much of the structure of freshwater wetlands further north. *Melaleuca quinquenervia* within swamp forest of the Eurunderee sand mass appeared to provide a more dense tree stratum than was found in equivalent communities at Coomonderry Swamp. Myerscough & Carolin (1986) did not observe any differentiation of *Eucalyptus robusta* and *Melaleuca quinquenervia* on the basis of water depth. At Coomonderry Swamp *Melaleuca ericifolia* (and *Melaleuca linariifolia* where it occurs) often formed dense thickets in standing water while *Eucalyptus robusta* was generally restricted to the (fluctuating) water margin where fewer *Melaleuca* plants were located. Species common to Swamp Mahogany woodland at both sites included: *Leptospermum juniperinum, Baumea arthrophylla, Baumea articulata, Baumea juncea, Baumea rubiginosa, Gahnia sieberiana, Schoenus brevifolius, Villarsia exaltata and Callistemon citrinus.* Formation of hummocks by organic accumulation, with consequent ecotonal development to *Gahnia sieberiana,* was noted by Myerscough & Carolin (1986) and was also typical of undisturbed margins at Coomonderry Swamp (Fig. 2).

'Fringe forest' of the lake margins of the Eurunderee sand mass equated to some degree with *Casuarina–Melaleuca* woodland both at Coomonderry Swamp and at other south coast sites surveyed. Understory species in both regions were related to water depth, substrate and salinity. In this case also the dominant, *Melaleuca quinquenervia,* is replaced by *Melaleuca ericifolia* on the south coast of NSW.

The community termed 'swamp' by Myerscough & Carolin (1986) is structurally equivalent to sedgeland and open water communities at Coomonderry Swamp, but species composition differed substantially between the two locations. Only scattered *Melaleuca quinquenervia* and *Banksia robur* trees occurred in swamp at Eurunderree, whereas at Coomonderry, *Melaleuca ericifolia* formed large thickets within the sedgeland. However *Eucalyptus robusta* did not occur within the swamp proper at either location.

Dry sclerophyll communities often associated with coastal freshwater wetlands, such as *Eucalyptus botryoides* and *Eucalyptus pilularis* open-forest, are reasonably well represented in the Sydney region (defined by the Sydney 1:100 000 map sheet — see

Benson & Howell 1994). However, in the Sydney area, sedgelands (*Eleocharis–Typha* dominated) and wet meadow communities are poorly represented, while only remants of undisturbed freshwater wetlands (*Baumea* dominated) and swamp forest remain (Benson & Howell 1994). Where they are found, these communities closely resemble equivalent communities described in this report, but often contain greater numbers of introduced taxa (Benson & Howell 1994).

Comparison of Coomonderry Swamp with other wetlands surveyed

Ordination of transect data from a diverse range of other south coast region wetlands produced only one further variable correlated strongly with change in floristics, this being salinity. It is thus not surprising that both fresh wetland communities and estuarine communities (particularly *Melaleuca* and *Melaleuca/Casuarina* communities), above the influence of continuous inundation, are often similar.

Wet meadow, estuarine pastures and salt marsh Minor differences in wet meadow related to brackish incursions at Brundee Swamp and Terrara Swamp, and to disturbed dunal influences at Killalea. Adam et al. (1988) have attributed a decline in *Selliera radicans*, particularly in the Sydney region, to invasion by *Hydrocotyle bonariensis*. *Hydrocotyle bonariensis* is a dominant component in dry dunal and wet meadow communities at Killalea wetland where *Selliera radicans* is absent. The latter species is found at many nearby wetlands e.g. Lake Illawarra (Yassini & Clarke 1985) and Werri Lagoon and was plentiful in brackish meadow and saltmarsh at Brundee Swamp and in saltmarsh margins of estuaries surveyed further south where *Hydrocotyle bonariensis* was not encountered (Appendix 1) .

Triglochin striatum and *Cotula coronopifolia* occurred only sporadically in fresh, wet meadow at Coomonderry Swamp, but were prevalent in saline and brackish environments surveyed. These observations support the argument of Adam et al. (1985) that limiting effects in wetlands more often relate to competition among species rather than an inability to tolerate particular conditions of inundation or salinity. Zedler et al. (1995) have suggested that *Triglochin striatum* may have a competitive advantage in areas of saltmarsh where trampling by cattle provides waterlogged recesses. Numbers of this species observed in areas at Brundee Swamp (brackish) and Werri Lagoon (saline) subject to trampling by cattle support this contention.

Both *Triglochin striatum* and *Cotula coronopifolia* are facultative halophytes while other species (e.g. *Lilaeopsis polyantha* and *Villarsia reniformis*) might be considered to be facultative glycophytes (in the sense that they tolerate salinity, but appear to be more competitively limited at saline sites than at freshwater sites). A robust form (phyllodes > 30 cm) of *Lilaeopsis polyantha* was intermittently prevalent in wet meadow at Coomonderry Swamp and this uncommon species has also been recorded at Wingecarribee Swamp in the adjacent highlands (Kodela & Hope 1992) but also, in contrast, at the tidal margins of Werri Lagoon. Coomonderry Swamp supports perhaps the largest population of the uncommon running marsh flower, *Villarsia reniformis*, yet this species was also recorded in smaller numbers at some estuarine and brackish sites (Appendix 1).

Intensive sampling in a one hectare area at the southern edge of Coomonderry Swamp detected examples of complex hybridization in taller Juncaceae. Both *Juncus polyanthemus* and *Juncus procerus* (as well as the introduced *Juncus cognatus*) were found at this site beyond their previous known ranges. Hybrids between these two species, between *Juncus polyanthemus* and *Juncus usitatus*, and between *Juncus continuus* and *Juncus usitatus* were recorded (L. Johnson Nat. Herb. pers. comm.). Several *Juncus* spp. co-occurred at other sites, and more intensive sampling should elicit further examples of hybridization. For example at Brundee Swamp, *Juncus kraussii, Juncus continuus, Juncus polyanthemus* and *Juncus mollis* co-occurred and Johnson (1993) has previously found hybridization in the latter two species.

Several *Persicaria* spp. are co-dominants in wet meadow at Coomonderry, Brundee and Killalea swamps and an undescribed form of *Persicaria lapathifolia* was recorded for Coomonderry Swamp (P. Kodela Nat. Herb. pers. comm.). Co-occurrence, new forms and the potential for hybridization in this genus have also been noted for wetlands of the Nepean-Hawkesberry system (J. Howell & D. Benson Nat. Herb. pers. comm.) Interactions among co-occurring members of this genus require further examination.

Just as the dynamics of wet meadow precluded finer community divisions, transect analysis at saline sites also supported fewer rather than more divisions within saltmarsh. Cluster analysis of saltmarsh transects produced an erratic grouping of quadrats in response to the mosaic of dominant species encountered. Carne (1989) recorded similar patterns in estuarine vegetation at Minnumurra River (Fig. 1). He related these to 'geomorphology through the landform attributes of microtopography and substrate composition' which had consequential effects on salinity and waterlogging. Carne (1989) did not differentiate between saltmarsh communities in his work. Zedler et al. (1995) also proposed a single saltmarsh community which might be variously dominated by *Sporobolus, Sarcocornia* or *Triglochin*. Clarke (1993) preferred recognition of only five truly saltmarsh complexes (in addition to Mangrove, *Juncus* and associated complexes) even though his study at Jervis Bay (Fig. 1) found 16 'communities' analogous to the 25 'communities' described by Adam et al. (1988). The prevalence of *Juncus kraussii* in assemblages classified as saltmarsh in this report (Fig. 4) suggests that *Juncus kraussii* is often an integral member of saltmarsh communities rather than a dominant member of dryer, peripheral communities.

A relatively species-rich assemblage of estuarine pasture species (community transect unit We3a — Fig. 4), clustered as saltmarsh, has developed under a regime of continuous grazing and an inundation regime manipulated to mitigate local flooding. It supports an interesting mix of species (Appendix 1), including *Bacopa monniera* and *Isolepis platycarpa*, two species well beyond their previous known southern limits.

Undisturbed freshwater margin Woody species associated with the undisturbed eastern margin of Coomonderry Swamp — *Eucalyptus robusta, Melaleuca* spp., *Leptospermum juniperinum, and Casuarina glauca* were also encountered in varying combinations at a number of other wetlands (Appendix 1). However the *Eucalyptus robusta* stand at Coomonderry Swamp was by far the largest and least degraded of any site surveyed. Nor were other sites characterised by a meadow-like understory of *Hemarthria uncinata* and *Villarsia exaltata.*

Open-forest *Eucalyptus* open-forest was the predominant vegetation type on sandier soils above most wetlands surveyed. However the development of littoral rainforest within open-forest seen at Coomonderry Swamp is a rare occurrence (Mills & Jakeman 1995). The only similar stand adjacent to wetland can be found on Comerong Island at the mouth of the Shoalhaven River (Fig. 1), and at Jervis Bay on sand dunes where the water table is high (Mills 1995).

Conservation of Coomonderry Swamp

A part of Coomonderry Swamp is protected within National Park, the wetland is listed as an important wetland (ANCA 1996) and has recently been listed on the register of the National Trust of Australia (NSW) (de Jong & Kodela 1995). However increasing urban and agricultural development could result in an altered hydrological regime and diminished water quality, as well as increases in the incidence of fire, weeds and feral animal invasion. Comprehensive faunal surveys have not been carried out although various unpublished surveys and the report of Lawler and Porter (1991) indicated that Coomonderry Swamp forms, with other wetlands of the Shoalhaven River system, an extremely valuable avian environment and a significant refuge for migratory water birds in times of inland drought. While rigorous faunal assessment is overdue, the present study demonstrates the primary standing of Coomonderry wetland as a reference site for restoration of freshwater wetland plant communities in the southern region of NSW. As such, Coomonderry Swamp requires equivalent protection as its counterpart, Jervis Bay, which is now a recognized reference site for marine and estuarine communities (Clarke 1993).

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Appendix 1 **Vascular plant species recorded from nine wetlands (and humic soil margins) on the south coast of NSW.**

*	introduced taxon	•	at, or near (< 20 km), limit of known range (Harden 1990-93)
◊	protected species in NSW (Harden 1990-93)	••	beyond limit of known range (Harden 1990-93)
##	rare or uncommon species in NSW (Harden 1990-93)	Δ	new record for ecogeographic region (Harden 1990-93)
#	regionally rare, uncommon or poorly conserved species (after Benson & McDougall 1993-95)		
?	insufficient material for positive identification at that wetland		

Bold type denotes abundance: ≥ 10% cover in any quadrat within a representative community

Nomenclature follows Harden (1990-93) and recent revisions accepted by the National Herbarium of NSW.

Communities (see Fig. 4)

DM:	dry meadow	WM:	wet meadow	DF:	deep freshwater	ME:	*Melaleuca*	SS:	Swamp mahogany - saw-sedge
SE:	sedgeland	OF:	open forest	GL:	grassland	SM:	saltmarsh	MA:	mangrove

Wetlands (see Fig. 1 & Table 1)

K:	Killalea Lagoon	We:	Werri Lagoon	C:	Crooked River	B:	Brundee Swamp	Te:	Terrara Swamp
P:	Pattimores Lagoon	Ta:	Tabourie Lake	Wi:	Willinga Lake	Co:	Coomonderry Swamp		

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
PTERIDOPHYTA										
AZOLLACEAE										
Azolla filiculoides var. *rubra*	K	Co	**Co**K	Co						

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
BLECHNACEAE										
● ◊ *Blechnum indicum*					Co					
B. cartilagineum							Wi			
Doodia asperata							Co			
DENNSTAEDTIACEAE										
Hypolepis muelleri		Co								
Pteridium esculentum				**P** Ta Wi	**Co**		**Co B P** **Ta Wi**			
GLEICHENIACEAE										
Gleichenia dicarpa					Co		Wi			
MARSILEACEAE										
Marsilea mutica		Co	**Co**							
SELAGINELLACEAE										
Selaginella uliginosa				Ta Wi			Ta			
GYMNOSPERMAE										
ZAMIACEAE										
Macrozamia communis							Co			
ANGIOSPERMAE										
- MONOCOTYLEDONS										
ALISMATACEAE										
Alisma plantago-aquatica		Co	Co							
**Sagitaria graminea* subsp. *platyphylla*	K		Co **K**							

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
ASPARAGACEAE										
**Protasparagus aethiopicus*								We		
ASPHODELACEAE										
*••*Trachyandra divaricata*	**K**									
COMMELINACEAE										
Commelina cyanea				Co			Co	We	We	
CYPERACEAE										
••*Baumea arthrophylla*			**Co**	**Wi**	**Co**	**Co**				
B. articulata			**Co** K	**Co**	**Co**	**Co**				
B. juncea				**P Ta Wi**	Co		Co		**P**	
B. rubiginosa					Co					
Bolboschoenus ?caldwellii		Te B	K							
B. fluviatilis		**Co**	Co							
Carex appressa		Co		Co				**Co**		
C. inversa	**K**									
**Cyperus brevifolius*		**Co**								
•*C. laevis*							Co			
Δ##••*C. odoratus*		Co								
C. polystachyos	**K**	Co **K** B		Co						
C. sanguinolentus		Co								

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
Eleocharis acuta	**K**	**Co K** **Te B**	**Co**	B				**B**		
**•E. minuta*		Co								
E. sphacelata		**Co**	**Co K**							
•Fimbristylis velata		CoK								
Gahnia sieberiana			Co	**Co P** **Ta Wi**	**Co**		**Co** C **Ta Wi**			
Isolepis cernua		Co **K**								
I. fluitans		Co B	**Co**	Co	Co	Co				
I. inundata		Co B		**Co Wi**						
I. nodosa	**K**						Ta			
Δ#I. platycarpa									**We**	
**I. prolifera*	**K**	**Co B**	**Co**	**Co**						
Lepidosperma laterale							Wi			
Schoenoplectus validus		Co **B** Te	**Co K**							
Schoenus brevifolius				**Ta** Wi	Co		**Ta**			
S. maschalinus		Co			Co					
S. nitens				Wi						
HYDROCHARITACEAE										
Ottelia ovalifolia			Co							
Vallisneria gigantea			K							

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
JUNCACEAE										
Juncus continuus		Co		B Wi	Co					
##*J. continuus* X *usitatus*							Co			
**J. cognatus*		Co						Co		
J. kraussii subsp. *australiensis*				**B** P **Ta Wi**			C	**We**	**We C** **B P**	
J. mollis				B					B	
J. planifolius		Co	Co	Wi						
••Δ*J. polyanthemus*		**Co Te B**	**Co**	B ?Wi					B	
J. polyanthemus X *usitatus*		Co								
##*J. polyanthemus* X *procerus*		Co	Co							
J. prismatocarpus		**Co K**	**Co**	**Co**	**Co**					
J. procerus		**Co**	**Co**	Co						
#*J. subsecundus*			Co							
J. usitatus		**Co**						Co		
JUNCAGINACEAE										
Triglochin procerum s. lat.		**Co** B	**Co** K	Co						
T. striatum	K	Co K Te B			Co				**We B P**	
LEMNACEAE										
•*Lemna ?disperma*			Co							
Spirodela punctata	K		Co K	**Co**						

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
LOMANDRACEAE										
Lomandra ?confertifolia subsp. *rubiginosa*							Wi			
L. longifolia				Wi			**Co** C**B** **Ta Wi**			
?Lomandra sp.							**C**			
LUZURIAGACEAE										
Eustrephus latifolius							Co Ta			
Geitonoplesium cymosum							Co C			
ORCHIDACEAE										
Acianthus ?fornicatus							Co			
Caladenia carnea var. *carnea*							Co			
Cryptostylis subulata					Co					
Dipodium ?punctatum							Co			
Spiranthes sinensis subsp. *australis*		Co		Wi						
PHILYDRACEAE										
Philydrum lanuginosum		Co B	**Co**	Co						
PHORMIACEAE										
Dianella caerulea var. *caerulea*					**Co**		Co Wi			
POACEAE										
Agrostis avenacea var. *avenacea*	**K**	**Co K**							**B**	
**Andropogon virginicus*		Co					Co			
**Axonopus affinus*		Co		Co	Co			Co		

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
**Bromus cartharticus*		Co						We		
Cynodon dactylon	**K**	Co		**Co**				We	We C	
Deyeuxia quadriseta				Ta Wi						
Dichelachne inaequiglumis							Co			
**Digitaria ciliaris*		Co								
**Echinochloa crus-galli*		Co **Te**						We		
Echinopogon caespitosus var. *caespitosus*				Ta			Co C			
Entolasia marginata				Co	**Co**		**Co C Wi**			
E. stricta				**B** Ta **Wi**	**Co**		**Co** C **Ta Wi**			
**Eragrostis mexicana*							Co			
Hemarthria uncinata				Ta **Wi**	**Co**					
**Holcus lanatus*	K	Co								
Imperata cylindrica var. *major*				**B Ta Wi**			**Co** C **B** Ta **Wi**			
**Lolium ?multiflorum* and hybrids		Co								
**L. perenne*	K									
Microlaena stipoides var. *stipoides*							Co			
Oplismenus aemulus				Co P Ta	**Co**		Co			
Panicum simile		Co					B			
**Paspalum dilatatum*		Co								

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
P. distichum		**Co** K **Te B**	**Co**	Co	Co					
*•*P. urvillei*		Co								
P. ?vaginatum	K								**We**	
**Pennisetum clandestinum*	**K**	**Co** Te		**Co**				**Co We**	**We** C	
**Phalaris angusta*		Co								
**P. aquatica*		Co ?K								
Phragmites australis				P **Ta Wi**	**Co**			We	**We** C **B** P	
**Polypogon monspeliensis*		Co							We	
Pseudoraphis paradoxa		**Co**	**Co**	**Co**	Co					
Sacciolepis indica		Co								
**Setaria gracilis*								We		
**S. pumila*								Co		
Spinifex sericeus	**K** Ta									
**Sporobolus indicus* var. *capensis*	K									
S. virginicus var. *virginicus*				**Ta**					**C**	**C**
**Stenotaphrum secundatum*							C	**We**	**We C**	
Themeda australis							Co			
Zoysia macrantha	**K**		**K**							

Communities	DM	WM	DF	ME	SS	SE	OF	GL	SM	MA
POTAMOGETONACEAE										
Potamogeton ochreatus			Co							
P. tricarinatus			**Co**							
Potamageton sp.				**Co**						
RESTIONACEAE										
◊••*Restio tetraphyllus* subsp. *meiostachyus*				**Wi**			**Co**			
SMILACACEAE										
Smilax glyciphylla					Co		**Co**			
SPARGANIACEAE										
Sparganium subglobosum		Co								
TYPHACEAE										
Typha orientalis	K	Co **K** B	**Co K** Te							
ZOSTERACEAE										
Zostera capricorni: deep estuarine at **We C Ta**										
ANGIOSPERMAE										
– DICOTYLEDONS										
AIZOACEAE										
Tetragonia tetragonoides								**We**	We C B	
AMARANTHACEAE										
Alternanthera denticulata	K	Co K		Co						

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
APIACEAE										
Apium prostratum var. *filiforme*									We	
Centella asiatica		Co		P						
**Hydrocotyle bonariensis*	**K**	Co K	K	Co						
H. peduncularis		**Co**								
##*Lilaeopsis polyantha*		K							We	
L. polyantha large phyllode form		Co								
APOCYNACEAE										
Parsonia straminea		Co		**Co**	**Co**		**Co**	**We**	C	
ASCLEPIADACEAE										
**Araujia sericiflora*								We		
Marsdenia rostrata							**Co**			
Tylophora barbata							C			
ASPARAGACEAE										
**Protasparagus aethiopicus*								We		
ASPHODELACEAE										
*••*Trachyandra divaricata*	**K**									
ASTERACEAE										
**Aster subulatus*	K	Co **K** **Te B**						We	We **B**	
**Bidens pilosa*								We		

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
*****_Bidens tripartita_		**Co**								
Centipeda minima var. _minima_		**Co**	Co	**Co**						
*_Chrysanthemoides monilifera_ subsp. _rotundata_								We		
*_Conyza albida_	K	Co		Ta			C			
*_Conyza parva_		Co								
*_Cotula coronopifolia_	K	Co **B**	**K**	B					**We B**	
Euchiton involucratum		Co								
*_Facelis retusa_		Co								
*_Hypochaeris glabra_		Co		Wi				**We**	**We**	
*_H. radicata_	K	**Co** K Te							We	
Lagenifera gracilis							Co			
#_Leptinella longipes_				Wi				**We**	**We**	
*_Onopordum acanthium_ subsp. _acanthium_			Co Te					We		
Ozothamnus diosmifolius				P			Co Wi			
Pseudognaphalium luteoalbum		Co K								
*_Senecio madagascariensis_	K	Co K Te	Co					We	We	
*_Sonchus asper_ subsp. _glaucescens_		Co								
*_S. oleraceus_		Co **K**	K							
Vernonia cineria var. _cineria_							Ta			
*••_Xanthium occidentale_		Te								

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
AVICENNIACEAE										
Avicennia marina var. *australasica*									C	**C**
BRASSICACEAE										
#*Cardamine paucijuga*		Co								
*##*Lepidium bonariense*								We		
CALLITRICHACEAE										
**Callitriche ?stagnalis*		Co								
CARYOPHYLLACEAE										
**Silene nocturna*	K									
*••*Spergularia marina*									We B	
CASUARINACEAE										
Allocasuarina littoralis							**Co**			
Casuarina glauca	**K**	Co **B**	**Co**	**Co B P** **Ta** Wi	**Co**	Co	C	**We**	**We C**	
CHENOPODIACEAE										
**Atriplex prostrata*									**We** C	
Chenopodium glaucum		K								
Suaeda australis									**C**	**C**
Sarcocornia quinqueflora subsp. *quinqueflora*								We	**We** C **P**	**C**
CLUSIACEAE										
Hypericum gramineum					Co					

Communities	DM	WM	DF	ME	SS	SE	OF	GL	SM	MA
CONVOLVULACEAE										
Dichondra repens							Co C		C	
#Polymeria calycina					Co					
CRASSULACEAE										
#Crassula peduncularis		**K**								
C. sieberiana	K									
DILLENIACEAE										
Hibbertia diffusa							B			
H. ?obtusifolia							Wi			
#H. scandens	**K**			Co P Ta			**Co C** **Ta** Wi			
DROSERACEAE										
Drosera spatulata				Wi	Co					
ELAEOCARPACEAE										
Elaeocarpus reticulatus					Co		**Co Wi**			
ELATINACEAE										
#Elatine gratioloides		Co		Co	Co					
EPACRIDACEAE										
Leucopogon lanceolatus var. *lanceolatus*							**Co** Wi			
Monotoca elliptica							**Co** Ta			

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
ESCALLONIACEAE										
Polyosma cunninghamii							C			
EUPHORBIACEAE										
Breynia oblongifolia				P			**Co** C Ta Wi			
##*Chamaesyce sparrmanii*	K									
#*Glochidion ferdinandi* var. *ferdinandi*					Co		**Co**			
Poranthera microphylla							Co			
FABACEAE - FABOIDEAE										
Daviesia ulicifolia							**B**			
Desmodium brachypodum							Co			
•*D. rhytidophyllum*							Co			
D. varians				Ta			Co C			
Glycine clandestina species complex				Ta Wi			Co C B Wi			
Hardenbergia violacea							Wi			
Kennedia rubicunda				B Wi			Co C **B** **Ta** Wi			
Pultenaea daphnoides							Wi			
P. retusa				B Wi			B			
**Trifolium repens*	K	**Co** B						**Co**		
FABACEAE–MIMOSOIDEAE										
Acacia falcata							B			
A. implexa							**Co** P			

Communities	DM	WM	DF	ME	SS	SE	OF	GL	SM	MA
A. longifolia	K			**B P** **Ta** Wi	Co		Co ?C **B** Ta **Wi**			
A. mearnsii							Co			
A. suaveolens							Co			
A. ulicifolia							Co			
FUMARIACEAE										
**Fumaria* sp.		Co								
GOODENIACEAE										
•*Goodenia heterophylla* subsp. *eglandulosa*							Co			
G. ovata				**P** Wi			Wi			
G. paniculata		Co		B Wi	**Co**					
Selliera radicans				**P** Wi				We	**We B P**	
HALORAGACEAE										
Gonocarpus micranthus subsp. *micranthus*					Co					
G. teucrioides							Co Ta Wi			
?*Haloragis heterophylla*							Wi			
*•*Myriophyllum ?aquaticum*		B								
•*M. simulans*	?K	**Co** ?K ?B	**Co**	Co	**Co**					
•*M. verrucosum*		K								

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
HYDROCHARITACEAE										
Vallisneria gigantea			K							
LAMIACEAE										
*•*Plectranthus ?ciliatus*								We		
LAURACEAE										
Cassytha pubescens				**B P** Ta **Wi**			C Ta			
*•*Cinnamomum camphora*				**Co**						
LENTIBULARIACEAE										
Utricularia australis			**Co**	Co	**Co**					
U. dichotoma					Co					
LOBELIACEAE										
Lobelia alata		Co		**Co**	Co					
Pratia purpurascens				B **P**			Wi			
LYTHRACEAE										
Lythrum hyssopifolia		Co							B	
MALVACEAE										
**Sida rhombifolia*				Co						
MENISPERMACEAE										
Stephania japonica var. *discolor*							Co C			
MENYANTHACEAE										
Villarsia exaltata		Co	**Co**	Co	**Co**	**Co**				
V. reniformis		Co	**Co**	Co	Co	**Co**				

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
MYOPORACEAE										
Myoporum acuminatum							Co			
M. boninense subsp. *australe*							**Co C**			
MYRTACEAE										
Angophora floribunda							Co			
Callistemon citrinus					Co					
Eucalyptus botryoides				**P Ta Wi**	Co		**Co C** **Ta Wi**			
E. botryoides × *saligna*							Co			
•*E. ?imitans*							B			
E. pilularis				**B**			**Co B** Wi			
#*E. robusta*				**Co B** ?Wi	**Co**	Co	**Co**			
#*Leptospermum juniperinum*		Co		**Wi**	**Co**	Co	Co Ta			
L. laevigatum	Ta									
L. polygalifolium subsp. *polygalifolium*				Wi						
Melaleuca ericifolia		**Co B**	**Co**	**Co B P** **Ta Wi**	**Co**		**C Wi**		**C**	
•*M. linariifolia*			**Co**	**Co**	**Co**		Co Wi			
•Δ*M. styphelioides*				Co **B**						
Syzigium australe							**C**			

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
NYMPHAEACEAE										
*Δ*Nymphaea alba* and hybrids		Co	**Co**	**Co**						
*•*N. capensis*			**Co**							
?•*Nymphoides geminata*				Co						
OLEACEAE										
Notelaea venosa							**C** Ta Wi			
ONAGRACEAE										
Ludwigia peploides subsp. *montevidensis*	**K**	Co	Co **K**	**Co**						
OXALIDACEAE										
*•*Oxalis corniculata*		Co								
O. perennans	K									
PASSIFLORACEAE										
#*Passiflora herbertiana* subsp. *herbertiana*							Co			
PHYTOLACCACEAE										
**Phytolacca octandra*				B						
PITTOSPORACEAE										
Billardiera scandens var. *scandens*				P			Co Ta Wi			
B. scandens var. *scandens/sericata* intergrade							Co B			
Pittosporum revolutum							Co **C**			
P. undulatum							**Co** C P			

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
PLANTAGINACEAE										
**Plantago lanceolata*	K									
POLYGONACEAE										
**Acetosella vulgaris*		Co								
Persicaria decipiens	K	**Co B**	Co	**Co**						
P. hydropiper		**Co**								
P. lapathifolia		Co **Te**								
P. lapathifolia (form with hairy underleaf)		Co								
P. orientalis		Co								
P. praetermissa		**Co**	**Co**	**Co** B				We		
**Polygonum aviculare*		**Te**							Te	
**Rumex crispus*		Co								
PRIMULACEAE										
**Anagallis arvensis*	K									
Samolus repens				Ta Wi					**We** C	
PROTEACEAE										
Banksia integrifolia subsp. *integrifolia*					**Co**		**Co Ta**	We		
B. serrata							**Co Ta**			
B. spinulosa var. *spinulosa*							Wi			
Persoonia linearis							**Co** ?B			

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
RANUNCULACEAE										
Clematis aristata							Co Wi			
Ranunculus inundatus	K	**Co** K **B**	K	B						
R. ?lappaceus				B						
ROSACEAE										
**Rubus* complex		Co						**Co**		
Rubus parvifolius							Co C			
RUBIACEAE										
Galium propinquum				Ta						
Opercularia aspera							Wi			
O. ?varia							Co B			
RUTACEAE										
##•*Melicope micrococca*							Co			
Zieria smithii subsp. A							Co			
SALICACEAE										
**Salix alba*		Co								
SANTALACEAE										
Choretrum candollei				Wi						
Exocarpus cupressiformis					**Co**		**Co**			
SCROPHULARIACEAE										
••*Bacopa monnieri*		**K**							**We**	
Gratiola pedunculata		Co								

Communities	**DM**	**WM**	**DF**	**ME**	**SS**	**SE**	**OF**	**GL**	**SM**	**MA**
Mimulus repens		K							**We**	
Veronica plebeia							Co			
SOLANACEAE										
**Lycium ferocissimum*								We		
Solanum americanum		Co								
**S. nigrum*								We		
**S. pseudocapsicum*									C	
STACKHOUSIACEAE										
Stackhousia viminea					Co					
STYLIDIACEAE										
Stylidium graminifolium							Co			
THYMELAEACEAE										
Pimelia linifolia subsp. *caesia*							B Wi			
Pimelia linifolia subsp. *linifolia*							Wi			
VERBENACEAE										
**Lantana camara*	**K**						**Co C**			
VIOLACEAE										
Viola caleyana		Co								
V. hederacea		Co		**Co** B Wi	Co		**Co** B Wi			
VITACEAE										
#Cayratia clematidea							Co			
Cissus hypoglauca							Co			

Vegetation and flora of Nearie Lake Nature Reserve, far western New South Wales

M.E. Westbrooke, J.D. Miller and M.K. Kerr

Westbrooke, M.E., Miller, J.D. and Kerr, M.K. (Centre for Environmental Management, University of Ballarat, P.O. Box 663, Ballarat, Victoria, Australia 3357) 1997 Vegetation and flora of Nearie Lake Nature Reserve, far western New South Wales. Cunninghamia *5(1): 129–137.* The vegetation of Nearie Lake Nature Reserve (lat 141° 52'E, long 33° 25'N), an overflow lake of the Great Darling Ana Branch in far western New South Wales, is described and a species list provided. Five vegetation communities have been identified and 150 vascular plant species recorded during surveys in 1995 and 1996. A further ten species recorded by Lloyd (1992) but not in this survey are noted.

Introduction

Nearie Lake is one of a number of periodically flooded lakes on the Great Darling Ana Branch in far western New South Wales (141°52'E, 33°25'N). It is located 80km north of Wentworth (Figure 1) and is at a height of 38m a.s.l. The water regime of the Ana Branch has been modified since the 1870s, when weirs were first built to control flows (Withers 1992). As a result of flood mitigation and water conservation measures the flood regime within the lake had been severely modified, water being held for longer at a lower level than would be the case from natural floods (Lloyd 1992). As a result of this change the *Eucalyptus largiflorens* community was threatened. A regulator was put in place in 1995 to control entry of water to the Lake. In future the Lake will only be flooded at times when this is considered likely to have occurred naturally, thought to be approximately one year in ten (Lloyd 1992). Nearie Lake was previously part of the Avoca Para pastoral lease but in 1973 it was assigned to the NSW National Parks and Wildlife Service for dedication and management as a nature reserve.

Land systems

The lake bed consists of heavy clay with a lunette to the south and east of white bleached sand. Gently undulating plains of sandy loams occur to the south and east of the lake (Walker 1991).

Vegetation

Nearie Lake is included in the Ana Branch-Mildura 1:250 000 map sheet, the vegetation of which was described by Fox (1991). A brief vegetation description was included in an environmental study conducted by Lloyd (1992) in which fifty vascular plant species were identified. During surveys in 1995 and 1996 one hundred and fifty vascular plant species were recorded from the reserve including 43 (30%) exotics. A further ten species recorded by Lloyd (1992) but not located and recorded during this survey are noted (Table 1).

Five vegetation communities were identified and mapped:

- Lake bed low open-herbland
- *Eucalyptus largiflorens* open-woodland
- *Atriplex nummularia* low open-shrubland
- *Maireana pyramidata* low open-shrubland
- *Nitraria billardieri* low open-shrubland

The distribution of these communities is shown in Fig. 2.

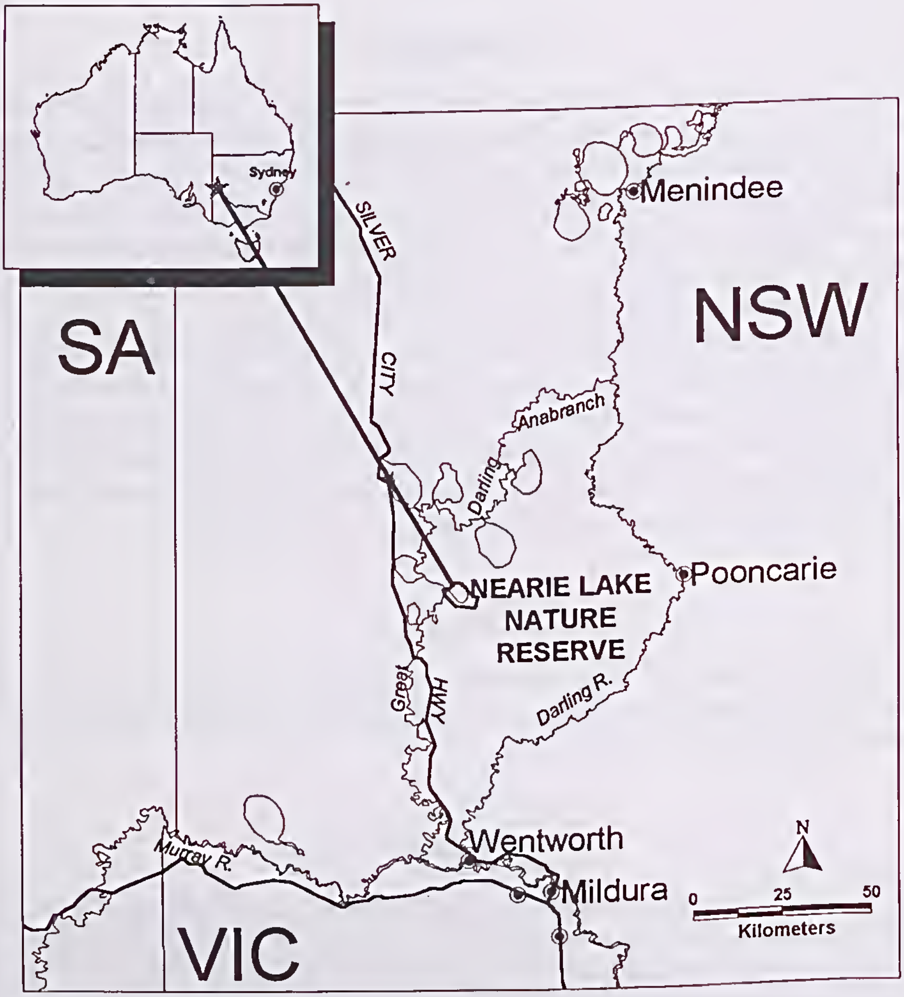

Fig 1. The location of Nearie Lake Nature Reserve.

Table 1 Vascular plant species recorded from Nearie Lake Nature Reserve.

Nomenclature according to Harden (1990-1993)
*denotes exotic species # denotes species recorded by Lloyd (1992) but not located and recorded in this study

MONOCOTYLEDONS

CYPERACEAE
Carex fascicularis
Cyperus gynocculus
LILIACEAE
*_Asphodelus fistulosus_
Bulbine bulbosa
Crinum flaccidum
POACEAE
Agrostis avenacea
Bromus arenarius
*_Bromus rubens_
Danthonia setacea
Enneopogon intermedius

POACEAE Continued
Eragrostis dielsii
Eragrostis lacunaria
*_Holcus lanatus_
*_Hordeum leporinum_
*_Lamarckia aurea_
*_Polypogon monspeliensis_
*_Rostraria pumila_
*_Schismus barbatus_
Sporobolus mitchellii
Stipa mollis
Stipa trichophylla
Vulpia myuros

DICOTYLEDONS

AIZOACEAE
#_Glinus lotoides_
*_Mesembryanthemum crystallinum_
*_Mesembryanthemum nodiflorum_
Tetragonia tetragonioides
APIACEAE
Dancus glochidiatus
ASTERACEAE
Actinobole uliginosum
Brachyscome ciliaris
Brachyscome dentata
Brachyscome lineariloba
Brachyscome melanocarpa
Brachyscome perpusilla
Calotis hispidula
*_Centaurea melitensis_
#_Centipeda cunninghamii_
*_Cirsium vulgare_

ASTERACEAE continued
*_Conyza bonariensis_
#_Epaltes australis_
*_Hypochoeris glabra_
*_Hypochoeris radicata_
Ixiolaena leptolepis
Minuria cunninghamii
Minuria intergerrima
Myriocephalus stuartii
Pseudognaphalium luteoalbum
Pycnosorus pleiocephalus
*_Reichardia tingitana_
Rhodanthe floribunda
Rhodanthe stuartiana
Senecio glossanthus
Senecio runcinifolius
*_Sonchus oleraceus_
Vittadinia cuneata
*_Xanthium spinosum_

BORAGINACEAE
*_Echium plantagineum_
Heliotropium asperrimum
Heliotropium curassavicum
#*_Heliotropium supinum_
*_Heliotropium europaeum_
Omphaloplappula concava
BRASSICACEAE
*_Alyssum linifolium_
Arabidella nasturtium
*_Brassica tournefortii_
*_Carrichtera annua_
*_Rapistrum rugosum_
*_Sisymbrium erysimoides_
*_Sisymbrium irio_
*_Sisymbrium orientale_
CAMPANULACEAE
Wahlenbergia communis s.l.
Wahlenbergia gracilenta s.l.

CARYOPHYLLACEAE
*Herniaria cinerea
*Spergularia rubra
CHENOPODIACEAE
Atriplex acutibractea
Atriplex angulata
Atriplex holocarpa
Atriplex leptocarpa
Atriplex lindleyi
Atriplex nummularia
Atriplex semibaccata
Atriplex stipitata
Atriplex vesicaria
Chenopodium cristatum
Chenopodium curvispicatum
Chenopodium desertorum
*Chenopodium murale
#Chenopodium pumilio
Chenopodium nitrariaceum
Dissocarpus biflorus
Dissocarpus paradoxus
Einadia nutans
Enchylaena tomentosa var. _tomentosa_
Maireana appressa
Maireana brevifolia
Maireana georgei
Maireana pyramidata
Maireana turbinata
Malacocera tricornis
Neobassia proceriflora
Osteocarpum acropterum var. _deminutum_
Rhagodia spinescens
Salsola kali
Scleroblitum atriplicinum
Sclerochlamys brachyptera
Sclerolaena bicornis
Sclerolaena diacantha
Sclerolaena divaricata
CHENOPODIACEAE continued
Sclerolaena intricata
Sclerolaena muricata
Sclerolaena obliquicuspis
Sclerolaena stelligera
Sclerolaena tricuspis
Sclerolaena ventricosa
Suaeda australis
CONVOLVULACEAE
Convolvulus erubescens
CRASSULACEAE
Crassula colorata
CUCURBITACEAE
*Citrullus lanatus
*Cucumis myriocarpus
# Zehneria micrantha
EUPHORBIACEAE
Chamaesyce drummondii
FABACEAE
Desmodium varians
Glycyrrhiza acanthocarpa
*Medicago minima
*Medicago polymorpha
*Medicago tornata
*Melilotus indicus
Swainsona reticulata.
Swainsona sp.
Trigonella suavissima
GERANIACEAE
*Erodium cicutarium
Erodium crinitum
GOODENIACEAE
Goodenia pinnatifida
HALORAGACEAE
#Myriophyllum verrucosum
#Limosella australis
LAMIACEAE
*Marrubium vulgare
Teucrium racemosum var. _racemosum_
LORANTHACEAE
Amyema miquelii
MALVACEAE
Lavatera plebeia
*Malva parviflora
MYRTACEAE
Eucalyptus largiflorens
PLANTAGINACEAE
Plantago drummondii
Plantago varia
PLUMBAGINACEAE
*Limonium lobatum
POLYGONACEAE
Muehlenbeckia diclina
Muehlenbeckia florulenta
Muehlenbeckia horrida
#Persicaria lapathifolium
Polygonum plebeium
*Rumex crispus
PORTULACACEAE
Calandrinia eremaea
SCROPHULARIACEAE
Morgania floribunda
SOLANACEAE
*Nicotiana glauca
Nicotiana velutina
*Solanum nigrum
URTICACEAE
*Urtica urens
VERBENACEAE
*Verbena officinalis
*Verbena supina
ZYGOPHYLLACEAE
Nitraria billardieri
Zygophyllum ammophilum
#Zygophyllum glaucum

The plant communities

1. Lakebed low open-herbland (Fig. 3)

The composition of this community is subject to change during and after periods of flooding. The persistent dominant, however, is *Muehlenbeckia horrida*. Associated species include the natives *Atriplex lindleyi, A. leptocarpa, Scleroleana divaricata, S. muricata, Osteocarpum acropterum* var. *deminutum, Vittadinia cuneata* and *Erodium crinatum* along with the exotics *Bromus rubens, Hordeum leporinum, Sisymbrium erysimoides* and *Medicago* spp. During the drying of Nearie Lake in 1995 this community was dominated by dense *Lavatera plebiea. Glycorrhiza acanthocarpa* occurs along Stoney Creek, the channel leading from the Ana Branch to the lake bed.

2. *Eucalyptus largiflorens* open-woodland (Fig. 4)

Around the edge of Nearie Lake is a semi-continuous open-woodland dominated by *Eucalyptus largiflorens* with a variable shrubby understorey including *Chenopodium nitrariacium, Muehlenbeckia horrida* and *Enchyleana tomentosa*. The herb layer consists largely of exotic weeds including *Medicago* spp., *Melilotus indicus, Sisymbrium erysimoides* and *Hordeum leporinum*. A high proportion of the *Eucalyptus largiflorens* are infected with the mistletoe *Amyema miquelii.*

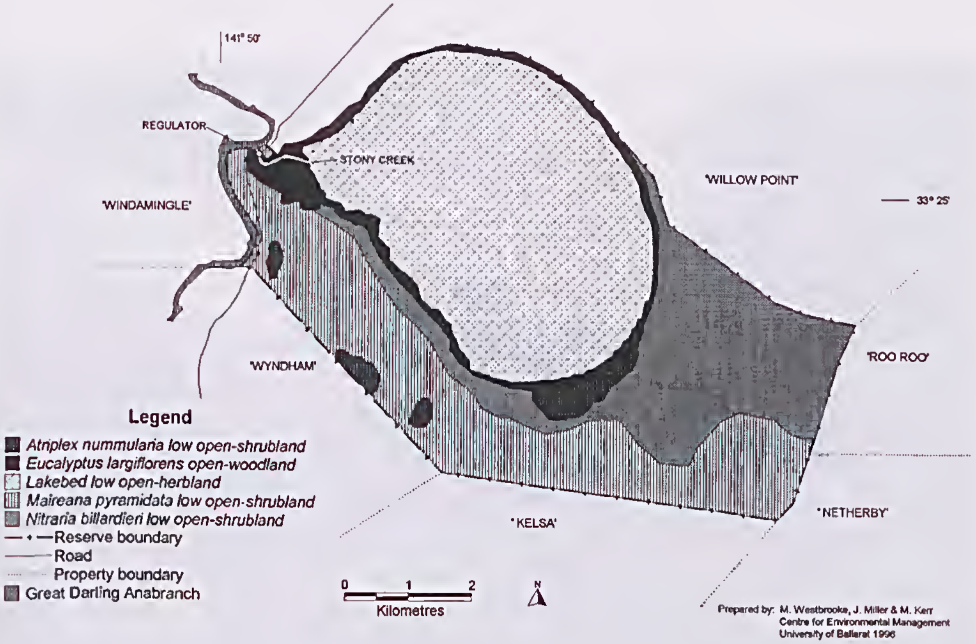
141° 50'
REGULATOR
STONY CREEK
'WINDAMINGLE'
'WILLOW POINT'
33° 25'
'WYNDHAM'
'ROO ROO'
'KELSA'
'NETHERBY'
Legend
▨ *Atriplex nummularia low open-shrubland*
■ *Eucalyptus largiflorens open-woodland*
☐ *Lakebed low open-herbland*
▥ *Maireana pyramidata low open-shrubland*
▨ *Nitraria billardieri low open-shrubland*
—+— Reserve boundary
—— Road
······ Property boundary
▨ Great Darling Anabranch
0 1 2
Kilometres
N
Prepared by: M. Westbrooke, J. Miller & M. Kerr
Centre for Environmental Management
University of Ballarat 1996

Fig 2. Vegetation of Nearie Lake Nature Reserve

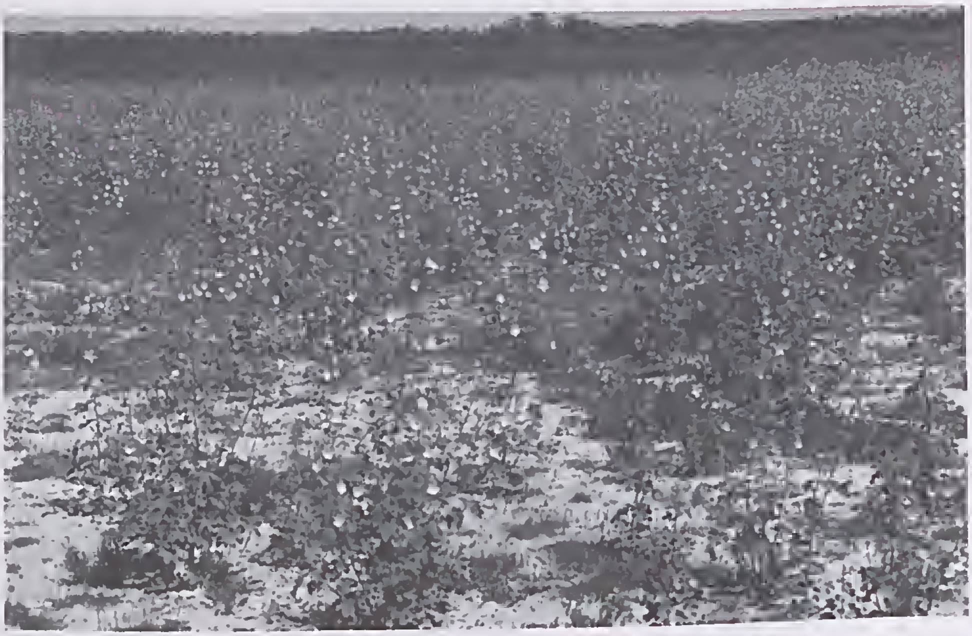

Fig. 3. The lakebed community dominated by *Lavatera plebiea* following drying of Nearie Lake in 1995.

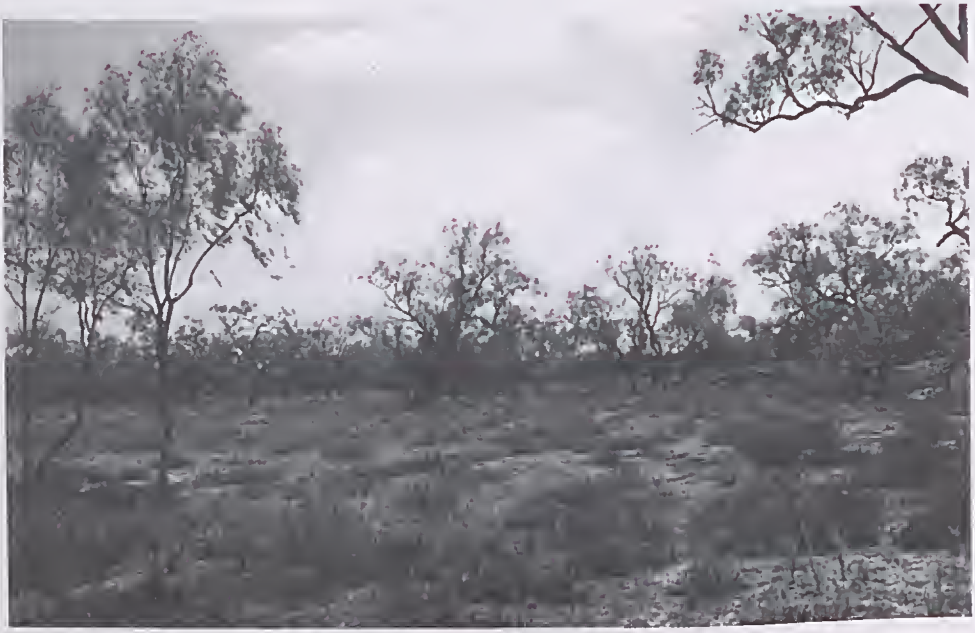

Fig. 4. Nearie Lake is fringed by *Eucalyptus largiflorens* open-woodland with a shrubby understorey.

3. *Atriplex nummularia* low open-shrubland (Fig. 5)

In depressions across the undulating plains to the south of Nearie Lake are areas dominated by *Atriplex nummularia* to a height of 2 m. Associated lower shrubs (to 1 m) include *Chenopodium curvispicatum, Nitraria billardieri, Scleroleana ventricosa* and *Enchyleana tomentosa.* The ground layer includes *Atriplex lindleyi* and *Osteocarpum acropterum* var *deminutum* along with the exotics *Schismus barbatus, Hordeum leporinum, Bromus rubens* and *Medicago* spp.

4. *Maireana pyramidata* low open-shrubland (Fig. 6)

On the undulating plains to the south of Nearie Lake are extensive areas of *Maireana pyramidata* low open-shrubland to 2 m. Associated shrubs include *Chenopodium curvispicatum, Maireana pyramidata, M. appressa* and *Atriplex lindleyi.* Following rains, the ground layer includes the natives *Plantago varia, Minuria intergerrima, Senecio runcinifolius, Tetragonia tetragonioides, Brachyscome lineariloba, Sclerochlamys brachyptera* and *Crassula colorata* along with the exotics *Hordeum leporinum, Bromus rubens, Schismus barbatus* and *Medicago* spp.

5. *Nitraria billardieri* low open-shrubland (Fig. 7)

To the east of Nearie Lake are extensive areas dominated by *Nitraria billardieri* to 2 m with associated shrubs including *Maireana pyramidata, M. turbinata, Scleroleana divaricata* and *Atriplex lindleyi.* The ground layer following rain is dominated by exotic herbs including *Sisymbrium erysimoides, Sonchus oleraceus, Bromus rubens* and *Medicago* spp.

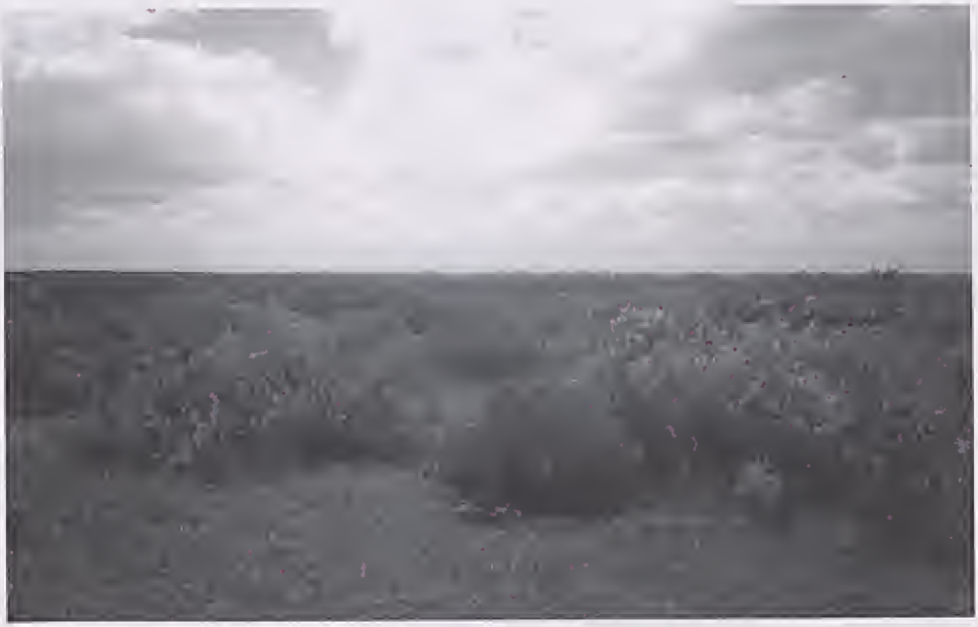

Fig. 5. *Atriplex nummularia* low open-shrubland occurring in depressions to the south of Nearie Lake.

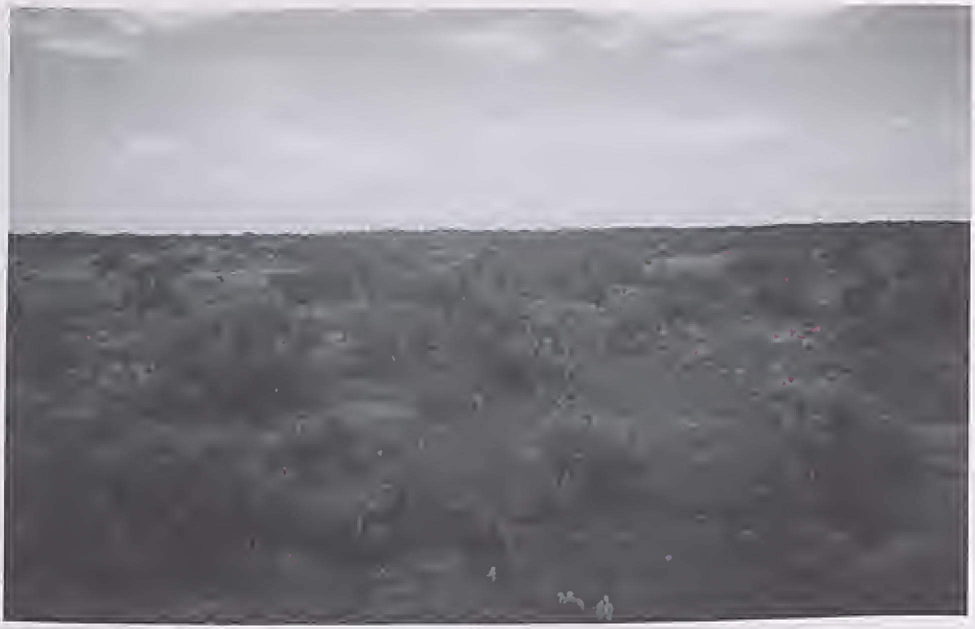

Fig. 6. *Maireana pyramidata* low open shrubland dominating the undulating plains to the south of Nearie Lake.

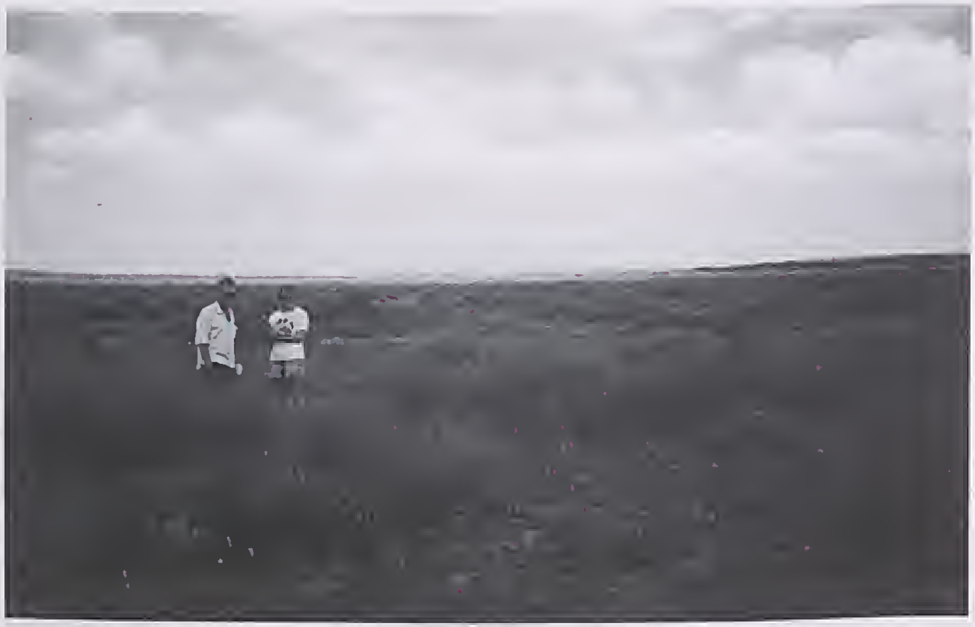

Fig. 7. *Nitraria billardieri* dominated low open-shrubland occurring to the east of Nearie Lake.

Discussion

Despite the high percentage of weediness in all communities (25–35%) and an overall weediness of 30%, Nearie Lake Nature Reserve is significant in protecting examples of the plant communities associated with the Darling Ana Branch. As a result of the water control measures, it provides a reference area for other parts of the river subject to a modified flooding regime.

Acknowledgments

We would like to acknowledge the assistance of George Townsend and Joanne Gorman of the National Parks and Wildlife Service, Buronga, for facilitating access to the site. The survey was carried out under the conditions of NPWS Licence A393.

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Manuscript accepted 16 April 1997

The natural vegetation of the Pooncarie 1: 250 000 map

Marianne F. Porteners, Elizabeth M. Ashby and John S. Benson

Porteners, Marianne F., Ashby, Elizabeth M. and Benson, John S., (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1997. The natural vegetation of the Pooncarie 1: 250 000 map. Cunninghamia *5(1): 139–231.* The composition and extent of the present native vegetation covered by the Pooncarie 1: 250 000 map sheet (33°00' to 34°00'S, 142°30' to 144°00'E) is described and mapped from quadrat samples and field traverses, aerial photography and LANDSAT Thematic Mapper satellite imagery. The study area is situated in south-western New South Wales and is almost wholly within the South Far Western Plains botanical subdivision. The landscape is typically continuous sandplains, dunefields and numerous dry lake basins, with a portion of alluvial plain in the south-east. Mallee shrublands and Belah-Rosewood open woodlands are the dominant vegetation types. Chenopod shrubland communities are also widespread. Nineteen vegetation communities are described and 330 species of vascular plants recorded from 62 families. 12% of the species recorded are exotic. The vegetation has been greatly modified and often degraded, principally due to grazing by introduced herbivores for over 150 years and by cropping of lake beds. Some large, relatively undisturbed areas of mallee vegetation still exist, due to their dense structure and inaccessibility. The poor conservation status of many of the vegetation communities is discussed.

Introduction

The Pooncarie 1: 250 000 map area is situated in far south-western New South Wales and contains a variety of semi-arid vegetation communities. A large expanse of mallee country is a major feature, as well as the chenopod shrublands associated with the Willandra Lakes system. These large dry lake beds were recognised for their archaeological values under a World Heritage listing in 1981. The area has a rich and ancient Aboriginal history as well as significant natural values. The major current land use is sheep grazing and other smaller-scale pastoral activities, with tourism to a much lesser extent. Exploration for mining of heavy metals is currently occurring around the Willandra Lakes. Areas of chenopod shrubland, lunette vegetation, Belah-Rosewood and mallee are protected within Mungo National Park, situated in the heart of the study area. Few undisturbed areas of vegetation exist today and many vegetation communities remain poorly represented or unrepresented in any conservation reserve.

Study area

The study area is covered by the Pooncarie Australian 1: 250 000 Topographic Survey sheet (SI 54–8) (Fig. 1). The eastern boundary of the mapped area is at longitude 144°00'E which runs east of Hatfield and west of Ivanhoe and Oxley. The western boundary runs west of Pooncarie at longitude 142°30'E. The northern boundary is south of the Sydney to Broken Hill railway line, at latitude 33°00'S. To the south, the boundary at latitude 34°00'S runs north of Mildura and Balranald.

The total area mapped is 1 524 900 ha, or approximately 138 × 110 kilometres, and falls within the Western Division of New South Wales. The majority of the land is under leasehold tenure. The only major township is Pooncarie, with a population of less than 100. Some large historical properties occur in the area, including 'Gol Gol', 'Arumpo', 'Mungo', 'Zanci', 'Garnpang' and 'Top Hut'. Mildura is the closest major centre to the study area, situated to the south-west, with the towns of Ivanhoe, Balranald and Wentworth to the north-east, south and south-west respectively. The mapped area is administered by the Balranald, Wentworth and Central Darling Shires. A network of unsealed roads links properties, towns and railway sidings while a small portion of the sealed Menindee Road occurs in the far west.

A dominant feature of the mapped area is the relict Willandra Lakes system, with Willandra Creek entering in the north-east. Large areas of sandplains and dunefields comprising parallel and irregular dunes are also conspicuous features. The area is situated directly west of the Hay Plain, the alluvial plain across which the Murray, Murrumbidgee and Lachlan Rivers flow westward from the eastern highlands. A small portion of the Hay Plain occurs in the south-east corner of the study area. A section of the Darling River also occurs in the far west.

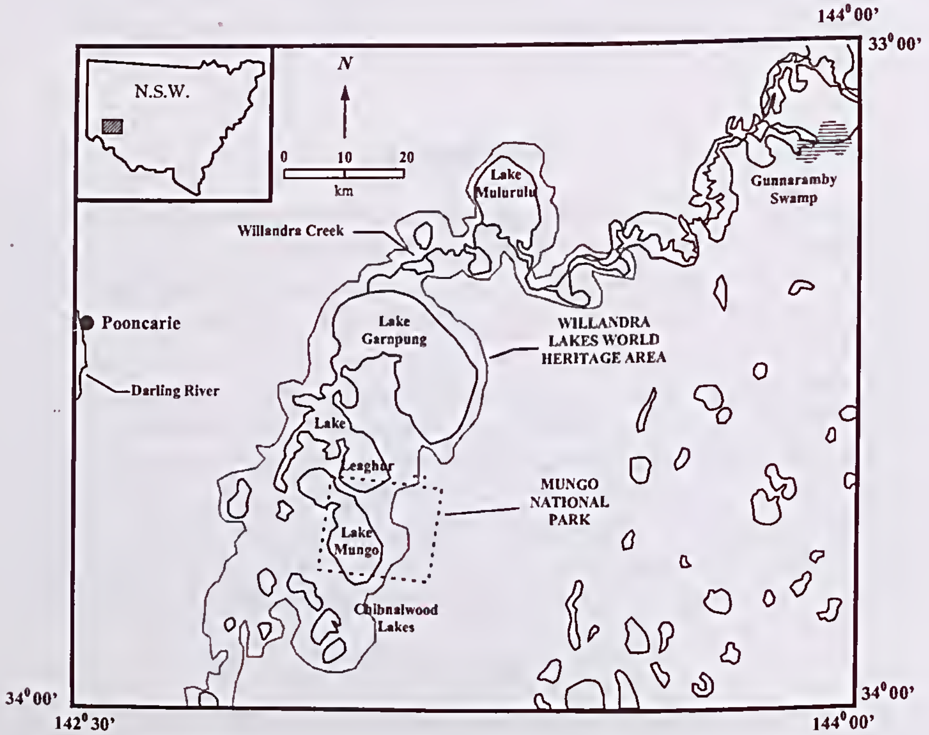

Fig. 1. Locality map of the study area.

Climate

The study area has a semi-arid climate, with hot summer temperatures, mild winters and a winter-dominant rainfall. Climatic averages for Pooncarie, Menindee, Balranald and Ivanhoe are presented in Fig. 2 (Bureau of Meteorology 1996). Daily temperatures fluctuate from hot days and cool nights in summer to mild days and cold nights in winter. The hottest month is January when the average daily temperature ranges from 16.4 to 32.6°C at Balranald. In July, the coldest month, this range is from 3.2 to 15.8°C

The rainfall is usually winter-dominant but can be erratic — the current survey was conducted between May 1994 and April 1995 during a period of severe drought. Follow-up spring rains peak in October, while the months of January, February and March have the lowest number of rain days (Bureau of Meteorology 1996). In south-western New South Wales, rainfall generally decreases northwards and becomes more evenly spread throughout the year. The average annual rainfall for Pooncarie is 267.5 mm, while at Ivanhoe it is 299 mm.

Geology

The study area lies within the Murray Basin of south-eastern Australia and consists of Tertiary and Quaternary sediments with a little rock outcropping (Pels 1969). Water and sediments were carried by Willandra Creek and the Lachlan River from the Eastern Highlands. In the east of the Basin, prior stream and more modern ancestral river deposits of sand, silt and clay, overlay an earlier terrestrial and lacustrine sequence. In the west, where the study area is located, Tertiary marine sediments are covered by a Pleistocene aeolian sequence which is part of the extensive desert dunefield of central Australia.

The Willandra Lakes are relict features from the Pleistocene, once filled by Willandra Billabong Creek, a former distributary of the Lachlan River (Pels 1969). Willandra Creek now diverges from the present Lachlan River near Hillston and continues to the Murrumbidgee near its confluence with the Murray River. The lakes were dry with conditions similar to today prior to about 45 000 years BP, but consequently filled, burying the old lunettes under clean quartz sands (Magee undated). Lake levels remained high until about 25 000 BP and the beach lunettes were vegetated. The sandy soils were formed under much less oxidising conditions than today or previously, and organic matter has been preserved. As a result, this soil contains many hearths and other archaeological material, associating this phase of the lake history with the most intensive human occupation.

Lake levels began to drop and oscillate seasonally after 25 000 BP and conditions became more saline. The region became extremely inhospitable during this drying phase of the last major glaciation, about 20 000 to 16 000 years ago. The lakes became very shallow and saline and thus during this period population levels of animals and humans dropped (Bowler & Magee undated). Accumulation of aeolian clays began from about 17 000 BP (in all but Lake Mulurulu), continuing for about 1500 years, representing the final depositional activity of the lakes.

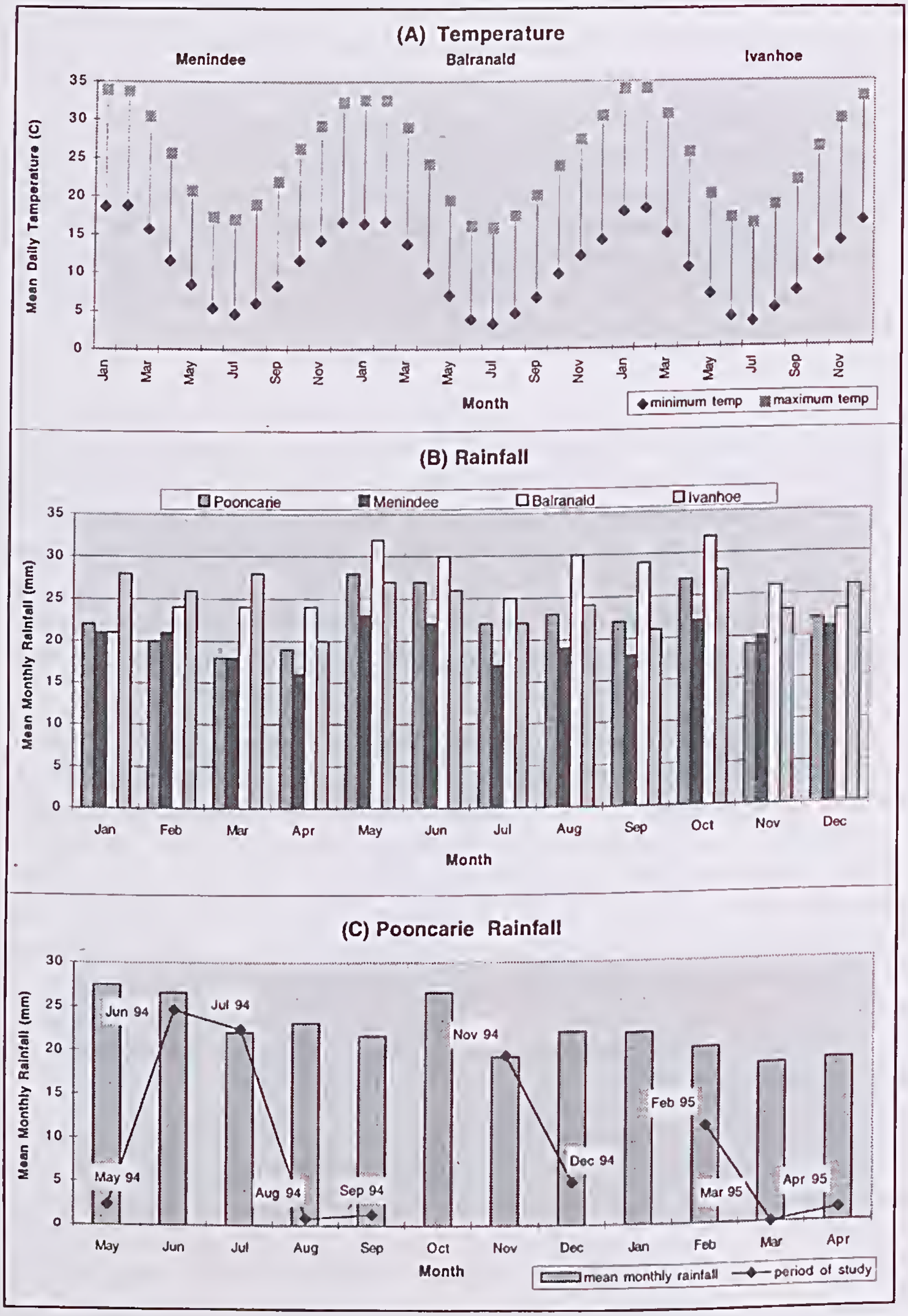

Fig. 2. Temperature and rainfall for the study area. Note that there were no rainfall data available for October 1994 and January 1995.

Concurrently, desert dunes were mobilised and lobes encroached onto lake floors, resulting in a contraction of the southern-most basins with intense deflation of material to form lunettes on their eastern margins. After 15 000 BP the landscape was largely stabilised by vegetation and the prevailing climatic conditions were similar to those of today. Lake Mulurulu experienced a later depositional phase, as it was higher in the drainage system and thus subject to more frequent flooding than downstream lakes. It had a brief high water phase at about 13 000 BP (Magee undated).

Palaeovegetation

Inland Australia was once much wetter, especially in the early part of the Tertiary (65 million years ago) from which rainforest taxa such as *Nothofagus* may be found in pollen assemblages of now arid and semi-arid regions (Martin 1989). Grasses formed only a minor component, there being no evidence of grasslands or open woodlands. Closed forests were present over most of southern and central Australia — the open savannah woodlands and grasslands now so typical of the modern Australian landscape did not become widespread until the Pleistocene, some 1.5 million years ago (Martin 1981).

In the late Miocene (approximately 10 million years ago) there was a profound change with *Nothofagus* disappearing and Myrtaceae becoming dominant. This is thought to coincide with an increase in fire and a decrease in rainfall. Mallee vegetation as we know it today probably did not develop until about Pliocene-Pleistocene (2 million years ago) and it probably reached its present proportions within the last million years (Martin 1989).

Geomorphology

The geomorphology of the study area is varied but dominated by aeolian dunefields and a system of large, dry lake depressions (Fig. 3). The Willandra Lakes system includes six major lake basins, numerous smaller lakes and connecting channels. The largest lake, Lake Garnpung, stretches for 30 km at its longest axis. The lake beds are shallow, sub-elliptical depressions with the long axes oriented north-west to south-east. Some of the lakes (usually those more downstream) have lake floor terracing. The western margin often has a steep bank or escarpment, while the eastern shoreline is marked by a crescent-shaped dune or lunette. The lunettes are formed by deposition of lake material by the prevailing westerly winds and vary in composition from clays to sands, reflecting the hydrology and lithology of the lake bed (Prendergast 1989). Lake Chibnalwood, for example, has a lunette that consists almost entirely of clay (Bowler & Magee 1978). In contrast, the nearby Walls of China lunette at Lake Mungo is made up of layers of quartz sand and saline sandy clay. This was actively eroding when the first European explorers came to the region (Magee undated).

Aeolian dunefields dominate the landscape and comprise both regular, linear dunes and irregular, subparabolic dunes. The dune ridges are relatively low in height and gradient compared to other active dune systems in Australia (Butler et al. 1973). The formation of the linear dunes overlapped with the final phase of lake activity in the region — where the longitudinal dunes intersect the lake margins they are truncated at the shoreline, indicating no dune activity since before the lakes were at their highest terrace levels (Magee undated). The irregular subparabolic dunes are superimposed on the linear dunefields and transgress onto the floor of the southern-most lake basins. There is also a distinct difference in the height and soil profile of these two dunefield types. Linear dunes, with their east-west alignment, are relatively low (2–6 m high) with gentle slopes, and contain siliceous sediments on the crests but are rich in clay and carbonate below. The steep, subparabolic dunes of irregular dunefields are usually higher than 10 m, with deep siliceous sediments and very small quantities of clay and carbonate in the subsoil (Wasson 1989).

Substantial sandplains also occur throughout the mapped area. Many of these consist of duplex soils with a thin veneer of sand overlying clay, particularly in the east and adjacent to the Darling River in the west. Clays are thought to underlie most, if not all of the sandplain areas (Semple & Eldridge 1989). Deeper sandplains merge into the aeolian dunefields. Sandplain areas are often slightly undulating and are characterised by irregular sand accumulations such as isolated dunes and sandhills. Some of these sandy rises, particularly in the east of the mapped area are derived from the sandy deposits of ancient streams (Butler et al. 1973).

A portion of riverine plain occurs in the south-east of the mapped area, representing its most western extent. The plain was formed during the late Tertiary and comprises clay sediments washed down from the eastern highlands by large, coalescing alluvial

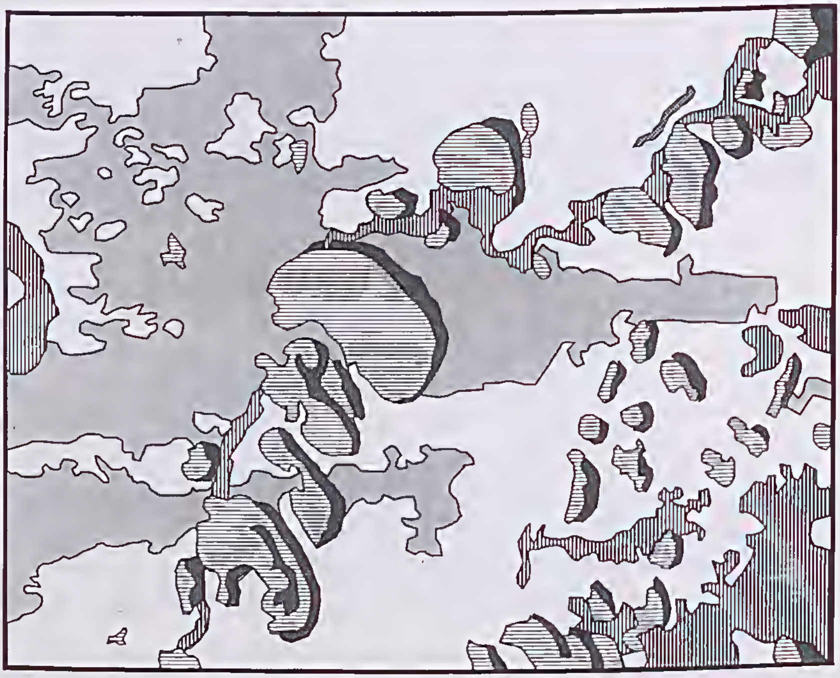

Fig. 3. Simplified physiographic units of the Pooncarie map sheet. Horizontal stripes = dry lake; vertical stripes = alluvial floodplain and riverine plain; checks = rocky outcrop; black = lunette; grey = parabolic and linear dunefield; white = sandplain. Derived from Cameron (1996).

fans (Butler et al. 1973). Within the study area, the plain is characterised by numerous depressions, scalds and isolated rises of sandy duplex soils.

The Darling River channel runs through the far west of the Pooncarie map and is deep and narrow in cross-section with steep banks. This and other rivers and creeks in the area carry a relatively large proportion of their sediment load in suspension, however many of these channels remain dry for years. The active floodplains associated with these contemporary streams are also much smaller in extent than the relict floodplains of the riverine plain.

Rocky outcrops of Palaeozoic sediments mark the edge of the Murray Basin (Semple & Eldridge 1989). The Manfred Range is a low, stony range of Upper Devonian sandstone, lying in the far north-east of the study area. Erosion of these and similar rocks during the Tertiary probably contributed to the quartz sands that comprise the surrounding plains (Bowler & Magee 1978).

Soils

The landscape of the study area is dominated by the red and orange sands of the mallee dunefields and sandplains (Fig. 3). These soils range from calcareous and siliceous sands to deep reddish-brown sands, increasing in carbonate content with depth (Semple & Eldridge 1989). Linear dunefields are composed of weathered sands with a dune core of finer texture, and are high in calcium carbonate. The soils of irregular and subparabolic dune systems are leached, non-calcareous, siliceous sands (Eldridge 1985). Calcareous sands are found more commonly on the flanks of these dunes while siliceous sands occur predominantly on the dune crests (Semple & Eldridge 1989). Characteristically, the crest of the dune has earthy sands grading to solonized brown soils on the flanks, and red-brown earths on adjacent flats which may include areas of grey, brown and red clays (Butler et al. 1983).

Sandy soils are also a common component of the aeolian and alluvial plains. The plains of the study area comprise clays and sands, becoming progressively more sandy and calcareous to the west. Much of the aeolian plain is underlain by clayey calcareous sediments and the upper layer of brown calcareous earths merges into deeper sandy dunefields (Eldridge 1985). Adjacent to the alluvial riverine plain in the east, sandplain areas are of hard-setting red duplex soils, with isolated sandy rises. These soils are highly susceptible to scalding and have high water-holding capacities due to the high clay content in the subsoil. The Manfred Range of Devonian sandstones and quartzites is blanketed in a covering of aeolian material. The soils of these rocky outcrops are shallow and dense, with a loamy and stony texture.

The soils of the riverine plain are grey, brown and red clays which increase in salinity to the west (Magee undated). Lake beds and drainage lines such as Willandra Creek have a thin, recent layer of grey clay merging to red-brown clay and overlying the fluvial and lacustrine clays (Eldridge 1985). The lake floors are dominated by clays, with silts and sands occurring on the eastern downwind margins (Bowler & Magee 1978). The lake floors of Mungo and Mulurulu consist of clays and sandy clays with occasional thin layers of quartz sands (Bowler & Magee undated). Generally the lake beds and basins of the Willandra Lakes system are composed of grey and yellow-grey cracking clays, with Willandra Creek and the northern and central lakes such as Leaghur, Garnpung and Mulurulu having margins of non-cracking clays. To the south, the clays of the relict lake beds and levees of Lakes Mungo, Arumpo and Chibnalwood are more yellow-grey, with the erosional remnants of duplex soils (Eldridge 1985). Channels and channel regions are characterised by a high percentage of silt, with shallow duplex soils of a red-brown sandy A-horizon, over a relatively impermeable, calcareous, clay-rich B-horizon (Bowler & Magee undated). The Darling River and other active rivers, creeks, floodplains, depressions, swamps and billabongs have beds of heavy, grey cracking clays.

Lunettes can be composed of either sand or clay. Quartz-rich lunettes were formed under full lake conditions by the deflation of sands from active beaches. Clay-rich and gypseous clay lunettes result from the subsequent reduction in the water table during the drying climate, an increase in water salinity resulting in granulation of the clay, strong winds to transport the clay from the drying basin floors and an increase in humidity to stabilise the lunette (Bowler & Magee undated, Eldridge 1985). Sandy lunettes (such as the Walls of China of Lake Mungo) comprise multiple layers of sediment which can be identified with their formative environmental conditions.

Aboriginal history

South-western New South Wales has a rich Aboriginal history, containing some of the oldest archaeological sites found in Australia. The best known lie in the Willandra Lakes World Heritage Region (Fig 1.) and include 30 000 year old campsites, shell middens, cooking pits, grinding stones, ochres and numerous stone tools. The most remarkable finds, however, have been the cremated and buried human remains, representing the world's oldest known ritual burials (Flood 1990).

Aboriginal people have lived in the Willandra Lakes region for at least 40 000 years, back to the Pleistocene when the climate was cooler and the lakes full of fresh water. The Willandra Lakes region showed great cultural continuity up until European contact as evidenced by the complex burial and cremation rituals, consistency in the use of ovens and hearths for cooking and continuity of stone tools (Magee undated). The Aboriginal community lived a subsistence lifestyle adapting to the seasonal changes in the lake resources. Life was concentrated around the lakes during the summer and during the winter the majority of the population was dispersed throughout the semi-arid plains (Magee undated). Tindale (1974) records the people inhabiting mallee lands in south eastern Australia as being highly mobile, unlike the more sedentary people of the rivers. The Darling River was occupied by the Paakintji people and many campsite remains have been found in sand dunes along the river, dated to at least 10 000 years (Lans et al. 1988). A large campsite was established on the river sandhills immediately opposite the present-day Pooncarie cemetery. At the time of European arrival, Pooncarie was known as 'Bilbarka' (Lans et al. 1988).

European exploration, settlement and land use

In 1830, on his second expedition, Captain Charles Sturt entered the lower reaches of the Darling River. He found it wide and deep, with the banks 'sloping and grassy, and were overhung by trees of magnificent size' (Sturt 1833). In 1836, Major Thomas Mitchell investigated the Darling River up to 30 miles to the north of its confluence with the Murray and 'soon found all the usual features of the Darling; the hills of soft red sand near the river, covered with the same kind of shrubs seen so much higher up' (Mitchell 1839).

It was not until 1844, when Edward John Eyre came to the area, that the lower Darling was explored. He reached a point on the Darling 70 miles north of the Murray — almost as far as Laidley's Ponds (present-day Menindee) — but ill-health forced him to turn back. He reported that '... the banks of the river were lined with most beautiful gum-trees, gracefully overhanging and with a wide-spreading dense foliage to the very ground. I have nowhere seen in Australia so picturesque an effect produced by the eucalypti as was the case along the whole course of the Darling' (reported in Lans et al. 1988). The treacherous nature of the alluvial soils was also noted: '... the strong tenacious character of the soil in the alluvial flats bordering upon the river caused it to open into deep holes and cracks, rendering it both difficult and dangerous to ride over them' (reported in Lans et al. 1988). Later that same year Sturt conducted an exploration of the interior, travelling up the Darling from the Murray to Laidley's Ponds and then heading west.

The lower Darling River was surveyed in 1848 by Surveyor Francis McCabe. At this time there were already squatters occupying land along the river (Lans et al. 1988). One of these squatters was William Campbell who named his run on the Darling River 'Pooncaree', from the Aboriginal *pooncaira* meaning large sandhill (Lans et al. 1988). By 1860, the year the Victorian Overland Expedition headed by Robert O'Hara Burke and William John Wills came to the Darling, most of the river frontage land was taken up and Laidley's Ponds was a village called Menindee. The first successful navigation of a paddle steamer up the Darling River occurred in 1859 and by 1860 they were transporting supplies and wool between Menindee, Pooncarie and Morgan in South Australia (Lans et al. 1988). Pooncarie became a vital link to river transport for the district but there were long periods when the river was dry and overland hauling teams would once again have to be used. Boats were still active on the Darling River up to the early 1900s when railways took over.

Prior to the 1920s there were a number of large pastoral holdings in the Pooncarie and Willandra Lakes district. For example, 'Gol Gol' was originally 200 000 ha. This was subdivided into smaller holdings in 1922 (Magee undated). In the early 1940s settlers were illegally grazing sheep and cattle on the land between the Murrumbidgee and lower Darling Rivers (Lans et al. 1988). Woodcutting was another activity carried out in the River Red Gum forests. Leased holdings were taken up by the late 1940s and existing larger stations such as 'Tarcoola' were divided into smaller leases ranging from 6 000 to 14 000 hectares (including 'Kinross' and 'Birdwood').

Today pastoral leases vary in size from an average of 20 000 hectares up to 70 000 hectares (Magee undated). The main land use activity is still grazing sheep for wool production. An increase in tourism in the area has resulted from the listing of the Willandra Lakes World Heritage Region (226 211 ha total, 208 262 ha of which is on the

Pooncarie map) and the gazetting of Mungo National Park. Interest has been shown in the heavy metal deposits of the sand dunes and exploration for sand mining has been undertaken by mining companies.

Previous botanical surveys

Until recently, the only detailed vegetation map for western New South Wales was the (approximately) 1: 1 000 000 map produced in the late 1940s by Noel Beadle, then botanist for the Soil Conservation Service in Condobolin (Beadle 1948). In the late 1950s and early 1960s Stannard mapped the vegetation of the central-east Darling region (directly north of the current survey area) and the Cobar Peneplain, during erosion surveys of these regions (Stannard 1958, 1963). The Royal Botanic Gardens Sydney have published a series of vegetation maps at 1: 250 000 scale for far south-western New South Wales. These include the maps to the west, south and east of the Pooncarie sheet: the Ana Branch-Mildura (Fox 1991), Balranald-Swan Hill (Scott 1992), Booligal-Hay and Deniliquin-Bendigo maps (Porteners 1993). To the north and north-west of the study area, the Royal Botanic Gardens has published a map at the scale of 1: 1 000 000, showing broad vegetation types (Pickard & Norris 1994). A grassland survey has also been conducted in the southern Riverina to the east of the current study area (Benson et al. 1997). Land Systems Maps have been published for the whole of the Western Division of New South Wales (including the Pooncarie 1: 250 000 map area), describing the recurring patterns of vegetation, soils and topography (Walker 1991).

The Willandra Lakes World Heritage Region (which occupies 13% of the Pooncarie map sheet) has been well documented for its natural and archaeological attributes. The Willandra Lakes were not even shown on locality maps until 1967 — names were chosen based on the properties occupying the greatest area of the lake (Pels 1964, 1969). A series of geomorphic maps were completed by Bowler and Magee (1978) and soils were mapped by Eldridge (1985) soon after. Under the National Estates Program of the Department of Planning, a study of the Willandra Lakes World Heritage Region was conducted and four broad vegetation types were mapped (Rice 1986). More recently, the vegetation of Mungo National Park was mapped at 1: 50 000 scale by Westbrooke and Miller (1995) and fauna surveys were undertaken in mallee areas by the NSW National Parks and Wildlife Service (Western Biodiversity Survey) and the Wilderness Society (Stage 2 of an assessment of wilderness areas in western New South Wales).

Methods

Sampling

Sites were selected to sample combinations of LANDSAT photo patterns, geomorphology, soil type and geology. LANDSAT TM images (1: 100 000 scale) of Arumpo, Hatfield, Mulurulu, Manfred, Pooncarie and Turlee sheets were inspected and broad patterns of vegetation pattern and geomorphology delineated (e.g. mallee on sand dunes, dry lake bed shrubland). The northern edge of the study area was not covered by the LANDSAT images, so 1: 50 000 scale colour aerial photographs (June 1993) were used for the top of the Manfred, Pooncarie and Mulurulu sheets.

Twenty-seven field days (54 person days) were spent in sampling the vegetation. Forty-six sites were sampled in May 1994, 39 in September 1994 and 25 in March 1995. Sampling times were selected in order to capture maximum species diversity — during the flowering and fruiting periods after the winter rains — although the area was suffering drought at the time of study. A further 7 field days (14 person days) were spent ground truthing boundaries and vegetation descriptions in September 1996.

The vegetation was sampled at 110 sites, each site being a 50 × 20 m quadrat. Detailed locations and the physical attributes of these sites are given in Appendix 1. Most of the primary and secondary roads were traversed in vehicles for extensive ground-truthing of boundaries and community description. The locations of the roads and sites sampled are shown in Fig. 4.

All plant species were recorded in each quadrat and assigned a cover abundance rating based on a modified Braun-Blanquet 6-point scale (Poore 1955) (<1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–100%). The structure of the vegetation was described by the number, height, cover and dominant species of each layer. The soil type was noted for each site, as was an estimate of the degree and type of disturbance.

Plant species nomenclature conforms with that currently recognised by the National Herbarium of NSW and follows Harden (1990–1993).

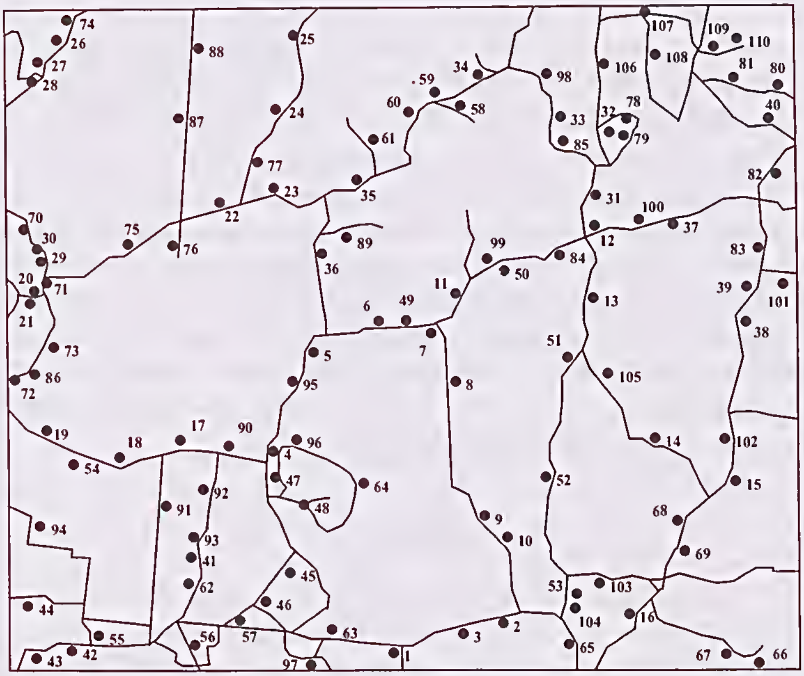

Fig. 4. Map of the study area showing sample sites and roads traversed.

Data analysis and mapping

All site data were entered into the floristic ecological database (Advanced Revelation) used at the National Herbarium of NSW. Data were investigated using multivariate techniques available in PATN (Belbin 1993) and other unpublished software (Bedward pers. comm.). The presence/absence of native species were used for analysis as this data set provided maximum information with minimum noise. Analysis of cover data was also undertaken for comparison.

A hierarchical agglomerative classification was used to describe groupings of species and sites (Belbin 1991). The Kulczynski coefficient of dissimilarity was used for its superiority in ecological applications (Belbin 1993). This coefficient describes the dissimilarity between sites based on their shared species composition; it places less emphasis than other coefficients on the absence of species. This is particularly relevant in a semi-arid rural landscape where species may be absent due to grazing or other past disturbance or immediate climatic conditions, rather than due to an inherent likelihood of occurrence. A hierarchical classification of sites was then derived from a clustering strategy using flexible unweighted pair group arithmetic averaging (UPGMA).

To check for misclassified sites in the resultant groups, a checking routine of nearest neighbours (Bedward, unpublished software) was used. This examines the nearest neighbours of all sites (as measured in the association matrix) and assesses whether any given site is grouped with its nearest neighbours. A misclassified site is one in a group where none of that site's nearest neighbours are present, and where none of the other sites in the group has that site as a nearest neighbour.

Once the groupings were finalised, a measure of fidelity to those groupings was generated for each species within that group (Bedward, unpublished software) to elucidate the contribution each species made to the definition of the group.

After sampling and analysis, further ground-truthing of boundaries and pattern-matching was carried out by traversing most of the primary and secondary roads. Provisional maps were drafted at 1: 100 000 scale and reduced to 1: 250 000 scale for final report and publication. The boundaries of the vegetation types were matched as closely as possible to the adjoining 1: 250 000 vegetation maps to the south (Balranald –Scott 1992) and to the east (Booligal–Porteners 1993). The vegetation map to the west (Ana Branch–Fox 1991) was produced using a different method and depicts pre-European, not present-day, vegetation. Thus, the Pooncarie vegetation boundaries were not closely matched with those on the Ana Branch map.

Results

Data analysis

The resulting dendrogram from the Kulczynski association and UPGMA clustering analysis (adjusted for misclassification) is shown in Fig. 5. Fifteen groupings representing 18 vegetation communities were defined at a dissimilarity measure of 0.75.

Broadly, the dendrogram reveals four main groups — the mallee communities of sandplain and dunefield, woodlands of the sandplain, shrublands of the lake beds and alluvial communities of the riverine plain and other major floodplains. The Mallee sites are most distinct, splitting off at the maximum dissimilarity measure.

The vegetation communities

The eighteen vegetation communities identified on the Pooncarie 1: 250 000 map sheet are summarised in Table 1. Open Areas (OA), Bare Areas (BA) and a cleared unit (C) are also recognised. The map unit names and numbers assigned to the communities follow on from previous mapping work on adjacent sheets (Scott 1992, Porteners 1993). There are, however, two minor differences. Scott (1992) defined Linear Dune Mallee (here denoted as 3b) more finely as Dune Crest and Dune Swale. Similarly, Scott (1992) defined two densities of Black Bluebush (8a and 8b) which is here only recognised as one density of Black Bluebush (8).

Structural types range from open herbfield and tussock grassland, to open forest, with mallee woodland and shrubland dominating. Community structure is based on Walker and Hopkins (1990). An asterisk * indicates an exotic species. The sites sampled within each community are listed; full site location information is given in Appendix 1. The mean number of native and exotic species (± standard deviation) per 50 × 20 m plot is also shown. The total number of native and exotic species recorded from each community is given in Table 2.

The community descriptions list the main, associated and common species found, as well as the soils, distribution, condition and conservation status of each type. **Main species** are mostly those that occurred in 80–100% of the sites in a community and are rarely or never found in another community. However, there are exceptions to both the commonness and exclusivity rules. Rocky Outcrop Woodland Complex (29) did not conform to the 80–100% occurrence rule due to the difficulty in capturing sufficient representative quadrats; the three Mallee communities (3a, 3b and 3d) have considerable species overlap; and Disturbed Shrubland Complex (22) contains disturbance-indicator species which are commonly found in other communities. To a certain extent main species may also be considered ‘indicator’ species for that particular community. However, that term has not been used due to the occasional species overlap. In most cases main species also define the community. Communities 1, 3a, 3b, 3d, 29 and 30 are also defined by their geomorphological associations and 22 by the condition of the community.

Associated species are those that occurred in 50–80% of the sites in that community. They are listed in descending order of frequency. Associated species usually constitute the understorey or ground-cover layers of the community. **Other common native species** are those that are considered as significant associated species in that community but were recorded in less than 50% of sites for that community (or 50% if only two sites were sampled for that community), or were recorded adjacent to a site. They are also listed in descending order of frequency. **Native species** recorded exclusively from each community are also listed, as well as all recorded **exotic species** in descending order of frequency.

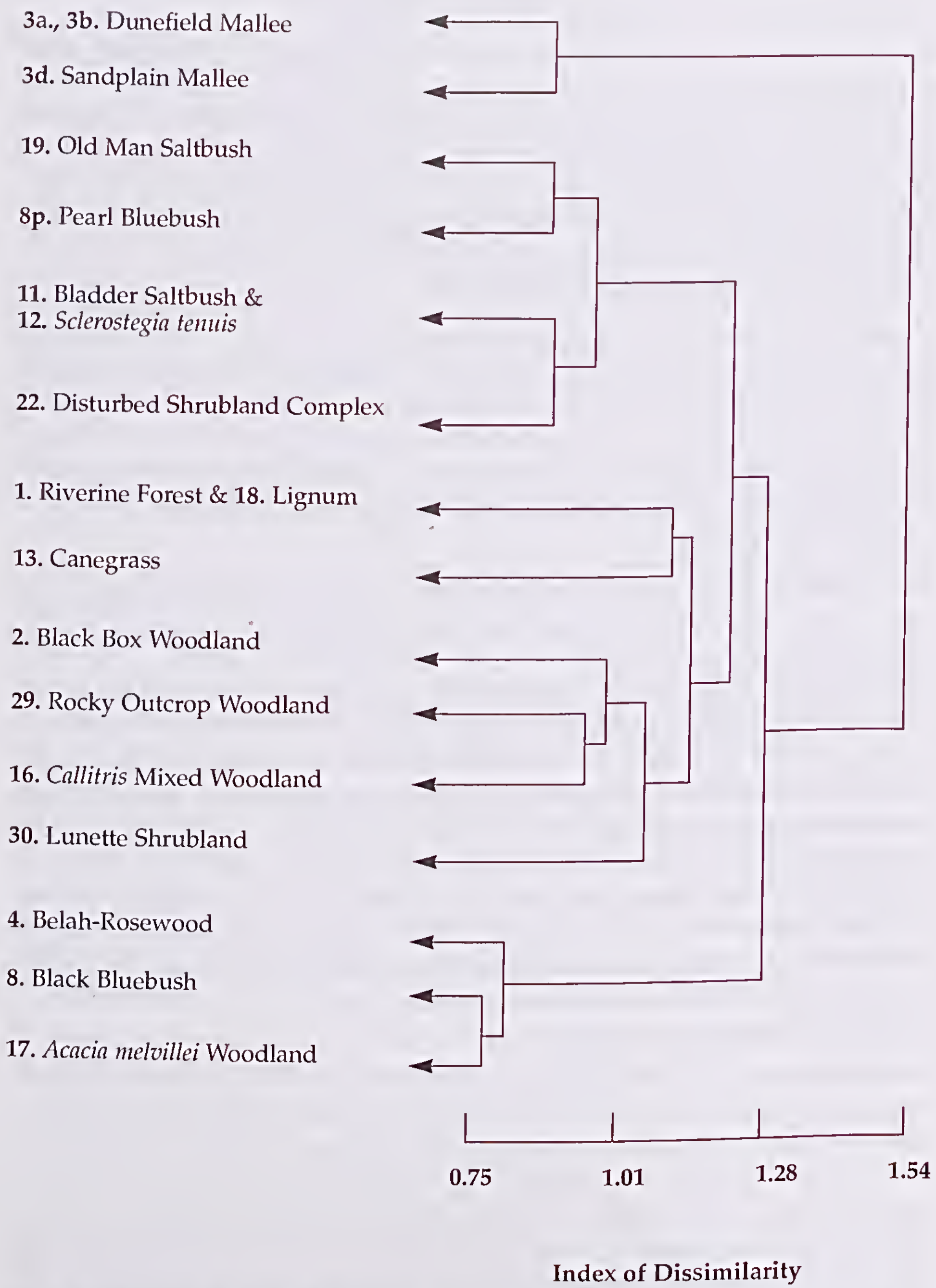

Fig. 5. Dendrogram showing 15 groupings representing 18 plant communities produced from Kulczynski association and UPGMA clustering.

Community descriptions

Vegetation community 1: Riverine Forest (Fig. 6)

Structure: open forest

Sample sites (n = 2): 021, 071

Mean no. native species/site: 16.0 ± 5.7

Mean no. exotic species/site: 6.0 ± 5.7 (27%)

Main species: *Eucalyptus camaldulensis* (River Red Gum)

Associated species: *Acacia stenophylla, Muehlenbeckia florulenta, Chenopodium nitrariaceum, Enchylaena tomentosa, Sclerolaena muricata* var. *muricata, Einadia nutans* subsp. *nutans, Atriplex leptocarpa, Panicum effusum.*

Other common native species: *Eucalyptus largiflorens, Marsilea drummondii, Oxalis perennans, Paspalidium jubiflorum.*

Native species recorded from this community only: *Eucalyptus camaldulensis, Atriplex suberecta, Swainsona greyana, Eclipta platyglossa, Paspalidium jubiflorum, Swainsona phacoides.*

Exotic species: **Heliotropium europaeum, *Cirsium vulgare, *Amsinckia intermedia, *Brassica tournefortii, *Bromus rubens, *Hypochaeris radicata, *Lycium ferocissimum, *Medicago polymorpha, *Sonchus oleraceus, *Vicia sativa* subsp. *augustifolia.*

Landform: River and creek levees, adjacent flats and associated billabongs and swamps, all subject to frequent or periodic flooding.

Soils: Self-mulching to silty grey clays; heavy grey and brown clays.

Distribution: This community occurs along the Darling River in the far central-west of the mapped area. Smaller creeks across the Pooncarie map area tend to be fringed with *Eucalyptus largiflorens* (Black Box), although *Eucalyptus camaldulensis* will occur where there has been periodic flooding.

Condition: Forests subject to manipulated flooding regimes with regeneration greatly affected; most older trees logged, resulting in regrowth of younger age class; weed infestation common; severe bank erosion along the Darling River.

Threats and conservation status: Areas of Riverine Forest along the Darling River are managed under leasehold tenure administered by the Western Lands Commission. The natural regeneration of trees is largely dependent on flooding (Allen 1979). The changes in flooding regimes caused by river regulation has led to a decline in the quality of stands (Margules & Partners et al. 1990). Weed infestation and bank erosion are also major problems exacerbated by current land use. Riverine Forest is not well reserved within New South Wales, being represented only in Kemendok Nature Reserve on the Murray River south-west of the mapped area and Kinchega National Park on the Darling River to the north. It is reserved within Hattah-Kulkyne National Park in north-western Victoria. Some small Crown Reserves contain Riverine Forest

Table 1. Vegetation communities of the Pooncarie 1: 250 000 map sheet showing main species and structural type. Structure is based on Walker and Hopkins (1990).

Vegetation Community	Main Species	Structure
1 Riverine Forest	*Eucalyptus camaldulensis*	open forest
2 Black Box Woodland	*Eucalyptus largiflorens*	woodland–open woodland
3a Irregular Dune Mallee	*Eucalyptus socialis* *Triodia scariosa* subsp. *scariosa*	mallee shrubland– open mallee shrubland
3b Linear Dune Mallee	*Eucalyptus socialis* *Eucalyptus dumosa* *Triodia scariosa* subsp. *scariosa*	mallee shrubland– open mallee shrubland
3d Sandplain Mallee	*Eucalyptus socialis* *Sclerolaena obliquicuspis* *Dissocarpus paradoxus* *Stipa nitida*	mallee shrubland– open mallee shrubland
4 Belah-Rosewood	*Casuarina pauper* *Alectryon oleifolius* subsp. *canescens*	open woodland–isolated clumps
8 Black Bluebush	*Maireana pyramidata*	chenopod shrubland–sparse chenopod shrubland
8p Pearl and Black Bluebushes	*Maireana sedifolia* *Maireana pyramidata*	chenopod shrubland–sparse chenopod shrubland
11 Bladder Saltbush	*Atriplex vesicaria*	chenopod shrubland–open chenopod shrubland
12 *Sclerostegia tenuis*	*Sclerostegia tenuis* *Disphyma crassifolium* subsp *clavellatum*	closed–open chenopod shrubland
13 Canegrass	*Eragrostis australasica*	tussock grassland
16 *Callitris* Woodland	*Callitris glaucophylla*	woodland–isolated clumps
17 *Acacia melvillei* Woodland	*Acacia melvillei*	isolated trees–open woodland
18 Lignum and Nitre Goosefoot	*Muehlenbeckia florulenta* *Chenopodium nitrariaceum*	open–closed shrubland
19 Old Man Saltbush	*Atriplex nummularia*	chenopod shrubland–open chenopod shrubland
22 Disturbed Shrubland Complex	*Dissocarpus paradoxus* *Nitraria billardierei*	shrubland–sparse shrubland
29 Rocky Outcrop Woodland Complex	*Callitris glaucophylla* *Eucalyptus intertexta*	open woodland–isolated trees
30 Lunette Shrubland	*Dodonaea viscosa* subsp. *angustissima*	shrubland–sparse shrubland
OA Open Areas	various grasses, herbs	grassland to forbland and forbs
BA Bare Areas	areas naturally bare of any vegetation	

areas, however these are usually discontinuous and generally not actively managed.

Key sites for conservation: River regulation has severely affected the Darling River and its associated forest within the study area. Blue-green algae outbreaks further upstream have contributed to the degradation of this once-robust river system. Although degraded, this Riverine Forest requires protection and recovery action.

Notes: Only a small area of this community occurs within the Pooncarie map area, and it forms the only forest structural type. Trees may reach heights of 40 m, and leaf and branch litter usually dominates the ground layer. The usually sparse understorey includes scattered shrubs of *Muehlenbeckia florulenta* (Lignum) and *Chenopodium nitrariaceum* (Nitre Goosefoot). *Eragrostis australasica* (Canegrass) may occur at intermittently flooded sites within this community, while areas of semi-permanent still water in oxbows and billabongs may support rushlands of *Typha* spp. and *Juncus* spp. The herbaceous layer varies seasonally and, as well as the species listed, may be

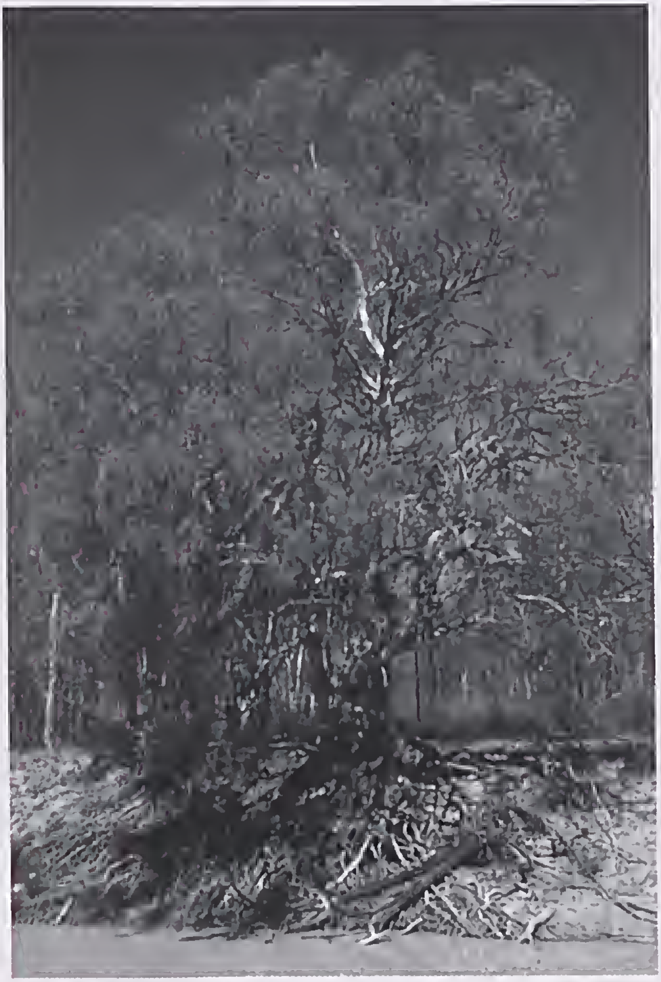

Fig. 6. *Eucalyptus camaldulensis* in Riverine Forest (Community 1) on the banks of the Darling River at Pooncarie.

dominated from year to year by *Alternanthera nodiflora, Eclipta platyglossa, Chamaesyce drummondii, Rumex brownii* and *Swainsona* spp.

Higher areas of red sands occur within the Darling River floodplain. These carry open woodlands and shrublands of *Callitris glaucophylla* and *Dodonaea viscosa* subsp. *angustissima* (See Community 16). Black Box Woodland (Community 2) is closely associated with Riverine Forest, occurring on the higher levels of the floodplain adjacent to the river.

Vegetation community 2: Black Box Woodland

Structure: woodland–open woodland

Sample sites (n = 6): 020, 030, 040, 072, 080, 110

Mean no. native species/site: 20.2 ± 7.8

Mean no. exotic species/site: 2.8 ± 2.6 (13%)

Main species: *Eucalyptus largiflorens* (Black Box)

Associated species: *Enchylaena tomentosa, Einadia nutans* subsp. *nutans, Atriplex semibaccata, Dissocarpus paradoxus, Salsola kali, Osteocarpum acropterum* var. *deminuta, Rhagodia spinescens, Sclerolaena muricata* var. *muricata, Atriplex eardleyae, Sclerolaena brachyptera, Solanum esuriale.*

Other common native species: *Chenopodium cristatum, Maireana brevifolia, Muehlenbeckia florulenta, Chamaesyce drummondii, Chenopodium nitrariaceum, Oxalis perennans.*

Native species recorded from this community only: *Goodenia heteromera, Isolepis australiensis, Juncus flavidus, Myriophyllum verrucosum, Radyera farragei, Ranunculus pumilio* var. *pumilio, Sclerolaena calcarata, Teucrium albicaule, Typha domingensis.*

Exotic species: **Cucumis myriocarpus, *Hordeum leporinum, *Brassica tournefortii, *Bromus rubens, *Carrichtera annua, *Chenopodium murale, *Hypochaeris glabra, *Lycium ferocissimum, *Medicago minima, *Sonchus asper* subsp. *glaucescens, *Spergularia rubra, *Tribulus terrestris, *Verbena supina, *Xanthium spinosum.*

Landform: Uppermost floodplain levels, ephemeral creeks and adjacent flats, dry-lake margins, depressions, drains and channels.

Soils: Silty or cracking, grey and brown clays.

Distribution: Black Box Woodland is not frequent across the mapped area, occurring in depressions, along minor creeks and fringing dry lakes. The greatest densities occur adjacent to *Eucalyptus camaldulensis* open forest on the upper levels of the Darling River floodplain. Black Box occurs in relatively dense stands in Gunnaramby Swamp in the far north-east, and along the channels of Willandra Creek.

Condition: Weed infestation common; understorey generally heavily grazed.

Threats and conservation status: Areas of Black Box Woodland are conserved in

Willandra National Park and Goonawarra National Park on the Hay Plain east of the study area, and in Yanga Nature Reserve near Balranald. Nevertheless, the community is considered poorly conserved in New South Wales (Murray-Darling Basin Ministerial Council 1987). Major threats to the community include disruption of natural flooding regimes needed for regeneration, and overgrazing of seedlings and other elements of the understorey.

Key sites for conservation: Gunnaramby Swamp (sites 040 and 080) in the north-east of the study area, is a notable wetland site containing large stands of Black Box Woodland. Other areas of this community, particularly those adjacent to the Darling River, are generally heavily grazed and cannot be singled out for special conservation action.

Notes: *Eucalyptus largiflorens* grows on the intermittently flooded areas of major river floodplains above the level of the more frequently flooded Riverine Forest. It occurs in ribbon stands along intermittent creeks, dry lakes and as scattered individual trees along drainage lines. The understorey is generally sparse, with chenopod species dominating. Above the Black Box, on the upper floodplain adjacent to the Darling River around Pooncarie, *Acacia victoriae* open woodland occurs, grading into areas of Belah-Rosewood and Sandplain Mallee.

Vegetation community 3: Mallee

Structure: mallee shrubland to open mallee shrubland (rarely open mallee woodland). The Pooncarie mallee is generally of the 'whipstick' type; a low, stunted multi-stemmed growth-form, indicating a sandy soil of low fertility and commonly occurring on the dune crests (Beadle 1948, Noble et al. 1980). 'Bull' mallee, a taller form with fewer stems, occurs in the heavier soils of the swales and is found less commonly on some sandplain areas in the east.

The most common mallee species in the region are *Eucalyptus socialis* (Pointed Mallee), *Eucalyptus dumosa* (Congoo Mallee), *Eucalyptus oleosa* (Glossy-leaved Red Mallee), *Eucalyptus leptophylla* (Narrow-leaved Red Mallee), *Eucalyptus costata* (Ridge-fruited Mallee) and *Eucalyptus gracilis* (Snap and Rattle). The continuous mallee area extends north to Menindee, north-east to Ivanhoe, south into the Murray and Lowan Mallees of Victoria, and west into South Australia. The mallee of central New South Wales (Yathong mallee) forms a large disjunct area between Cobar and Hillston to the north-east of the Pooncarie mallee (Pickard 1987, Pickard & Norris 1994, Conn 1993).

Vegetation community 3a: Irregular Dune Mallee

Sample sites (n = 16): 011, 013, 018, 019, 022, 025, 044, 054, 061, 064, 075, 076, 084, 091,094, 099

Mean no. native species/site: 15.8 ± 4.3

Mean no. exotic species/site: 0.1 ± 0.3 (1%)

Main species: *Eucalyptus socialis* (Pointed Mallee), *Triodia scariosa* subsp. *scariosa* (Porcupine Grass).

Associated species: *Sclerolaena diacantha, Eucalyptus dumosa, Acacia wilhelmiana, Sclerolaena parviflora, Stipa nitida, Dodonaea viscosa* subsp. *angustissima, Podolepis capillaris.*

Other common native species: *Eucalyptus leptophylla, Eucalyptus costata, Eucalyptus gracilis, Eucalyptus oleosa, Halgania cyanea, Lomandra leucocephala* subsp. *robusta, Maireana triptera, Chenopodium desertorum* subsp. *desertorum, Calotis erinacea, Sclerolaena obliquicuspis, Acacia rigens, Bossiaea walkeri, Duboisia hopwoodii, Leptospermum coriaceum, Ptilotus exaltatus* var. *exaltatus.*

Native species recorded from this community only: *Codonocarpus cotinifolius, Hibbertia virgata* subsp. *virgata, Acacia oswaldii, Beyeria opaca, Daviesia arenaria, Exocarpus sparteus, Olearia lepidophylla, Olearia passerinoides* subsp. *passerinoides, Pimelea simplex* subsp. *continua, Plantago cunninghamii, Dicrastylis verticillata, Grevillea pterosperma, Santalum murrayanum.*

Exotic species: **Salvia verbenaca.*

Landform: Dunefields with irregular or discontinuous linear or subparabolic dunes; dunefields of parabolic and unaligned dunes.

Soils: Deep, sandy red soils; leached, non-calcareous siliceous sands.

Distribution: Irregular Dune Mallee is the most common mallee type of the Pooncarie map and occurs throughout the map sheet area; large continuous tracts occur in the central-east and west.

Condition: Some areas cleared or thinned; soil erosion due to goat and rabbit infestation; areas of woody shrubs present; areas subject to wildfire; understorey plants grazed by goats.

Threats and conservation status: Although existing mallee reserves are spread over most of the mallee areas of the state (with the exception of the far west), there is still a need for widespread retention of mallee on Crown Lands held as Western Lands Leases (Brickhill 1988). Prescribed burning in mallee areas, grazing and clearing for dryland cropping are the major current threats to mallee vegetation.

Small areas of both Irregular Dune and Sandplain Mallee exist within Mungo National Park, the only reserve within the study area (Westbrooke & Miller 1995). A number of other reserves within the Central and Western Divisions of New South Wales also contain mallee areas. Mallee Cliffs National Park (58 000 ha) contains 75% mallee (Mabbutt 1982), a small proportion of which is dunefield mallee (16%) with *Triodia scariosa* subsp. *scariosa* understorey (Morcom & Westbrooke 1990). Nombinnie, Round Hill and Yathong Nature Reserves also contain mallee areas, mostly of the dunefield type with *Triodia* understorey (Cohn 1995). Tarawi Nature Reserve (to the west of the Pooncarie map) is a mallee reserve of over 33 000 hectares that contains mostly Irregular and Linear Dune Mallee systems along with Sandplain Mallee and Belah-Rosewood woodlands.

Key sites for conservation: Fine examples of this community occur in the west of the mapped area and form a relatively undisturbed wilderness. These expanses of mallee remain difficult to access and remote areas such as the locally named 'No Mans Land' paddock, south-east of Pooncarie, can only be reached by following fenceline tracks and firebreaks. This particular area on 'Arumpo' is unwatered, fenced-off and not utilised and has the potential to be an excellent wilderness reserve (Brickhill 1988, Green 1988). Other notable sites sampled during the present survey include 011, 013, 019, 044, 054, 061, 064, 076, 091 and 094.

Notes: Irregular Dune Mallee occurs on deep sands and differs from Linear Dune Mallee in its taller, shrubby understorey and denser *Triodia* layer. *Eucalyptus socialis, Eucalyptus dumosa, Eucalyptus leptophylla* and *Eucalyptus costata* are the dominant mallee species in this community with *Eucalyptus gracilis* and *Eucalyptus oleosa* occurring less frequently. *Eucalyptus oleosa* is more common on flatter country such as sandplains and low dunefields (Brooker & Kleinig 1983). Species such as *Eucalyptus costata, Calotis erinacea, Leptospermum coriaceum, Codonocarpus cotinifolius, Hibbertia virgata* subsp. *virgata, Dicrastylis verticillata* and *Grevillea pterosperma* are associated with the deep, well-drained sandy soils of this mallee community (Cunningham et al. 1981). *Codonocarpus cotinifolius* is a rapid-growing species commonly occurring in the mallee after fire (Harden 1990-93). Its presence may indicate a history of higher fire frequency than in other mallee communities.

Callitris glaucophylla and *Callitris verrucosa* (Mallee Cypress Pine) occur on higher ridges or dunes with deep sandy soils within the mallee. *Casuarina pauper* with *Alectryon oleifolius* subsp. *canescens* can also form local communities within the mallee, particularly in the swales of dunes.

Vegetation community 3b: Linear Dune Mallee (Fig. 7)

Sample sites (n = 9): 001, 008, 009, 043, 055, 063, 077, 088, 097

Mean no. native species/site: 21.6 ± 5.0

Mean no. exotic species/site: 0.2 ± 0.4 (1%)

Main species: *Eucalyptus socialis* (Pointed Mallee), *Eucalyptus dumosa* (Congoo Mallee), *Triodia scariosa* subsp. *scariosa* (Porcupine Grass), *Sclerolaena diacantha* (Grey Copperburr).

Associated species: *Dodonaea viscosa* subsp. *angustissima, Stipa nitida, Eucalyptus gracilis, Acacia colletioides, Enchylaena tomentosa, Eremophila glabra, Sclerolaena parviflora, Maireana triptera, Chenopodium desertorum* subsp. *desertorum*.

Other common native species: *Eucalyptus costata, Eucalyptus leptophylla, Eucalyptus oleosa, Halgania cyanea, Ptilotus exaltatus* var. *exaltatus, Salsola kali, Sclerolaena obliquicuspis, Zygophyllum apiculatum, Acacia wilhelmiana, Atriplex stipitata, Maireana pentatropis, Maireana sclerolaenoides, Vittadinia cuneata* var. *cuneata, Bossiaea walkeri, Chenopodium curvispicatum, Senna artemisioides* subsp. *petiolaris*.

Native species recorded from this community only: *Eutaxia microphylla, Dodonaea bursariifolia, Brachycome multifida* var. *multifida, Cynoglossum australe, Eremophila deserti, Goodenia varia, Grevillea huegelii, Olearia magniflora, Scaevola depauperata, Olearia subspicata, Opercularia turpis*.

Exotic species: **Asphodelus fistulosus, *Brassica tournefortii.*

Landform: Dunefields with continuous, east-west aligned linear dunes or parallel dunes with narrow swales.

Soils: Deep loamy sand to sandy red soil; weathered calcareous sands; calcareous loamy red earths in swales.

Distribution: Linear Dune Mallee occurs throughout the map sheet area, particularly in the central-south and far south-west.

Condition: Areas cleared or thinned; some soil erosion due to rabbit infestation and some scalding in open areas; areas of woody shrubs present; areas subject to wildfire; stands mostly of the 'whipstick' form.

Threats and conservation status: Threats as for Irregular Dune Mallee (3a). Very small

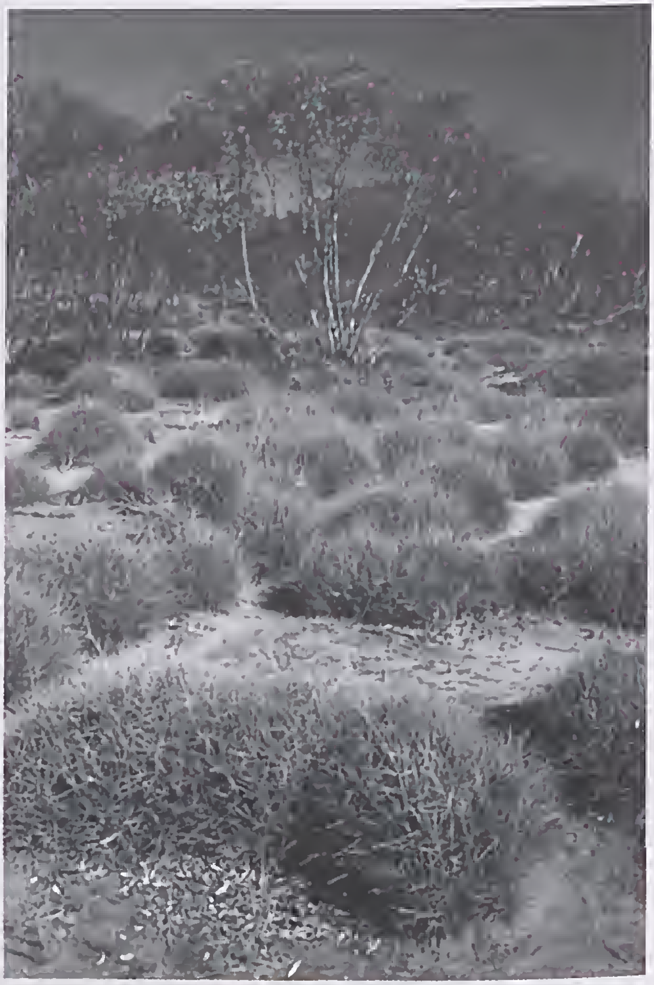

Fig. 7. Mallee on linear sand dunes (Community 3b) with dense *Triodia* hummocks; site 1 at Ryah Box Flat, near Mungo National Park.

areas of Linear Dune Mallee exist within Mungo National Park, but otherwise the community is not conserved within the mapped area (Westbrooke & Miller 1995). Mallee Cliffs National Park to the south contains areas of dune-crest mallee (Scott 1992). Nombinnie, Round Hill and Yathong Nature Reserves also conserve dunefield mallee (Cohn 1995).

Key sites for conservation: Several sites in the south of the mapped area are worthy of protection. Sites 097 and 063 south of 'Turlee' lie within a large continuous area of Linear Dune Mallee in good condition. Sites 008, 009, 043, 055 and 088 are also in good condition, but occur within fragmented mallee areas.

Notes: Linear Dune Mallee occurs on regular, generally east-west running dunes, with a low understorey of *Triodia scariosa* subsp. *scariosa* and mixed shrubs. *Eucalyptus socialis, Eucalyptus dumosa* and *Eucalyptus gracilis* are the dominant mallee species in this community, while *Eucalyptus costata, Eucalyptus oleosa* and *Eucalyptus leptophylla* may be co-dominant with any or all of the above. The understorey has a relatively high diversity of shrub and herb species compared to other vegetation communities. In areas of dense mallee that have remained unburnt for some years, ground litter is often high.

Callitris glaucophylla and *Callitris verrucosa* (Mallee Cypress Pine) occur on higher ridges or dunes with deep sandy soils within the mallee. *Casuarina pauper* with *Alectryon oleifolius* subsp. *canescens* can also form local communities within the mallee, particularly in the swales of dunes.

Vegetation community 3d: Sandplain Mallee (Fig. 8)

Sample sites (n = 11): 026, 027, 034, 039, 047, 052, 057, 070, 073, 098, 105

Mean no. native species/site: 14 .1 ± 3.8

Mean no. exotic species/site: 1.0 ± 1.3 (7%)

Main species: *Eucalyptus socialis* (Pointed Mallee), *Sclerolaena obliquicuspis* (Limestone Copperburr), *Dissocarpus paradoxus* (Cannonball Burr), *Stipa nitida* (Speargrass).

Associated species: *Eucalyptus dumosa, Eucalyptus gracilis, Enchylaena tomentosa, Maireana triptera, Sclerolaena diacantha, Atriplex stipitata.*

Other common native species: *Chenopodium desertorum* subsp. *desertorum, Salsola kali, Zygophyllum apiculatum, Maireana pentatropis, Maireana sclerolaenoides, Marsdenia australis, Sclerolaena patenticuspis, Eucalyptus oleosa.*

Native species recorded from this community only: *Acacia victoriae, Brachycome exilis, Calotis cuneifolia, Minuria denticulata.*

Exotic species: **Asphodelus fistulosus, *Hordeum leporinum, *Brassica tournefortii, *Bromus rubens, *Medicago polymorpha, *Medicago truncatula, *Sonchus oleraceus.*

Landform: Level to undulating sandplains, often with low, discontinuous, linear dunes.

Soils: Calcareous loamy sand to sandy red and brown loams; earths with sandy loam surface and red desert loams derived from aeolian materials.

Distribution: Sandplain mallee occurs throughout the map sheet area but is most common in the eastern half. It also occurs adjacent to the Darling River floodplain in the far west. The community tends to occur on deeper sandplains adjacent to areas of Belah-Rosewood.

Condition: Large areas cleared or thinned; some soil erosion due to rabbit infestation and scalding in open areas; areas of woody shrubs present; prone to weed infestation; some areas subject to wildfire; few old stands remain, mostly of the 'whipstick' form.

Threats and conservation status: Threats and status similar to other mallee types. A small portion occurs within Mungo National Park and fragmented areas within Mallee Cliffs National Park (Westbrooke & Miller 1995, Scott 1992). This particular mallee type is probably not adequately represented in any conservation reserve.

Key sites for conservation: None of the sites visited within this community can be singled out for special conservation recommendation as most were in a poor to average condition when sampled. The community is particularly fragmented and highly disturbed within the mapped area. Its potential for recovery with more favourable seasons is unknown.

Notes: Sandplain Mallee differs floristically from dune-type mallees in its low shrubby chenopod understorey, with little or no *Triodia scariosa* subsp. *scariosa* (Porcupine Grass). Chenopods form an understorey where the soils are higher in clay content, such as on sandplains, duplex plains and swales. Porcupine Grass is associated with the deeper sands of the dunefields. Ground litter is often high in areas that have remained unburnt for some years.

Throughout the mapped area, stands of *Callitris glaucophylla* and Belah-Rosewood occur intermixed with the sandplain mallee and also form local communities within it. *Acacia victoriae* open woodland occurs on the edges of this community, grading into areas of Belah-Rosewood. Large woody shrubs such as *Dodonaea viscosa* subsp. *angustissima*, *Myoporum platycarpum* and *Eremophila sturtii* are common understorey components in the more open and disturbed areas of sandplain mallee, particularly in the north-east of the mapped area. Sandplain or chenopod mallee extends south into the Victorian Murray Mallee and is dominated there by *Eucalyptus gracilis* and *Eucalyptus oleosa* (Conn 1993).

Vegetation community 4: Belah-Rosewood (Fig. 9)

Structure: open woodland–isolated clumps

Sample sites (n = 15): 003, 010, 012, 014, 023, 024, 033, 042, 046, 051, 060, 074, 079, 087, 106

Mean no. native species/site: 14.8 ± 4.0

Mean no. exotic species/site: 0.2 ± 0.4 (1%)

Main species: *Casuarina pauper* (Belah), *Alectryon oleifolius* subsp. *canescens* (Rosewood).

Associated species: *Enchylaena tomentosa, Sclerolaena obliquicuspis, Dissocarpus paradoxus, Stipa nitida, Sclerolaena diacantha, Atriplex stipitata.*

Other common native species: *Maireana triptera, Senna artemisioides* nothosubsp. *coriacea, Geijera parviflora, Myoporum platycarpum* subsp. *platycarpum, Eremophila sturtii, Callitris glaucophylla, Maireana pyramidata, Sclerolaena patenticuspis, Apophyllum anomalum, Dodonaea viscosa* subsp. *angustissima, Exocarpos aphyllus, Rhagodia spinescens, Flindersia maculosa* (in the far north of the mapped area).

Native species recorded from this community only: *Senna artemisioides* nothosubsp. *sturtii, Apophyllum anomalum, Rhagodia ulicina, Amyema miraculosum* subsp. *boormanii, Flindersia maculosa, Lepidium phlebopetalum, Minuria leptophylla, Scleranthus pungens, Acacia loderi, Eremophila maculata, Hakea leucoptera, Hakea tephrosperma, Myoporum montanum, Parsonsia eucalyptophylla.*

Exotic species: **Asphodelus fistulosus, *Salvia verbenaca.*

Landform: Level to undulating sandplains, often with isolated sandy rises.

Soils: Calcareous earths, mainly of red to red-brown loam to loamy sand; solonised brown soils to sandy red earths (Cunningham et al. 1981); reddish-brown sands and texture-contrast (duplex) soils (Scriven 1988).

Distribution: Belah-Rosewood is common throughout the Pooncarie map area. The most dense and continuous stands occur in the north to north-east.

Condition: Scalding and soil erosion, often severe, due to rabbit infestation; trees thinned or cleared in some areas; areas of woody shrubs present; few stands with understorey intact; heavily grazed.

Threats and conservation status: Heavy grazing of belah-rosewood areas has resulted in the thinning and clearing of much of the understorey. Undermining of the sandier soils by rabbits has caused further degradation and the duplex soils are also susceptible to scalding. Belah-Rosewood communities of the region are showing severe stress and dieback with little regeneration due to grazing pressures (Morgan & Terrey 1992).

Clumps of *Casuarina pauper* and *Alectryon oleifolius* subsp. *canescens* often survive by suckering and regeneration is prevented by grazing (Semple & Eldridge 1989). *Casuarina pauper* does not maintain a soil seedbank and must rely on annual seed production and the irregular rainfall to promote germination and establishment (Auld 1995). *Alectryon oleifolius* subsp. *canescens* rarely regenerates from seed and depends on disturbance events such as fire to produce root suckers (Wisniewski & Parsons 1986). Fire frequency may need to be considered in the management of this species to perpetuate stands.

Some small areas of this community are conserved within Mungo National Park and other small reserves, but it is considered inadequately conserved over its range (Benson 1988).

Key sites for conservation: Areas of Belah-Rosewood with intact understoreys should be preserved and protected wherever possible, particularly if regenerating. Sites 010 and 106 in the east of the mapped area were noted as being in good condition.

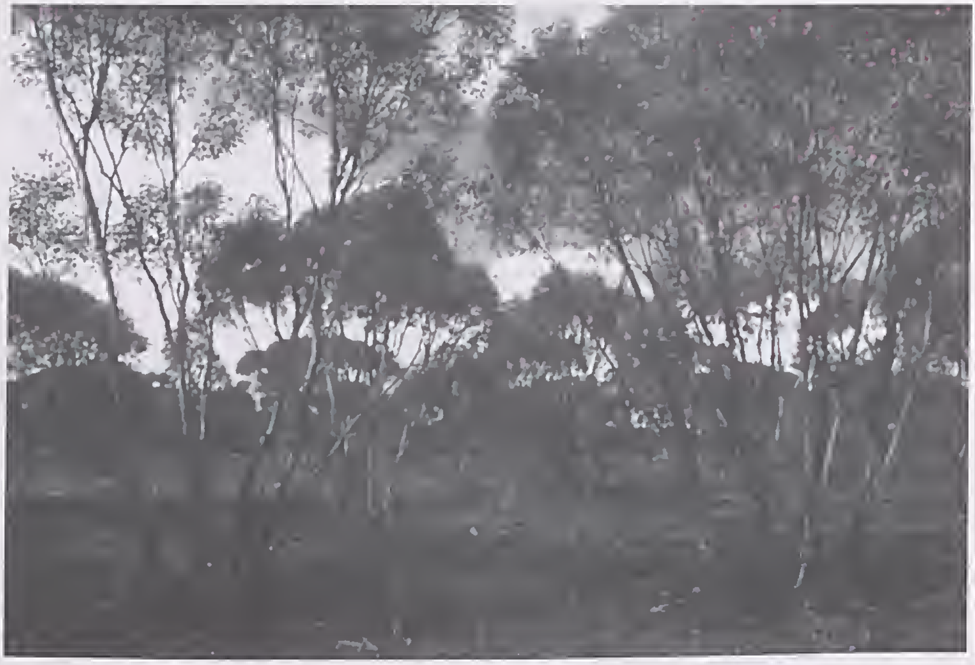

Fig. 8. Mallee of the sandplain (Community 3d) has an open understorey of chenopod shrubs; site 34 on the Garnpung to Darnick road.

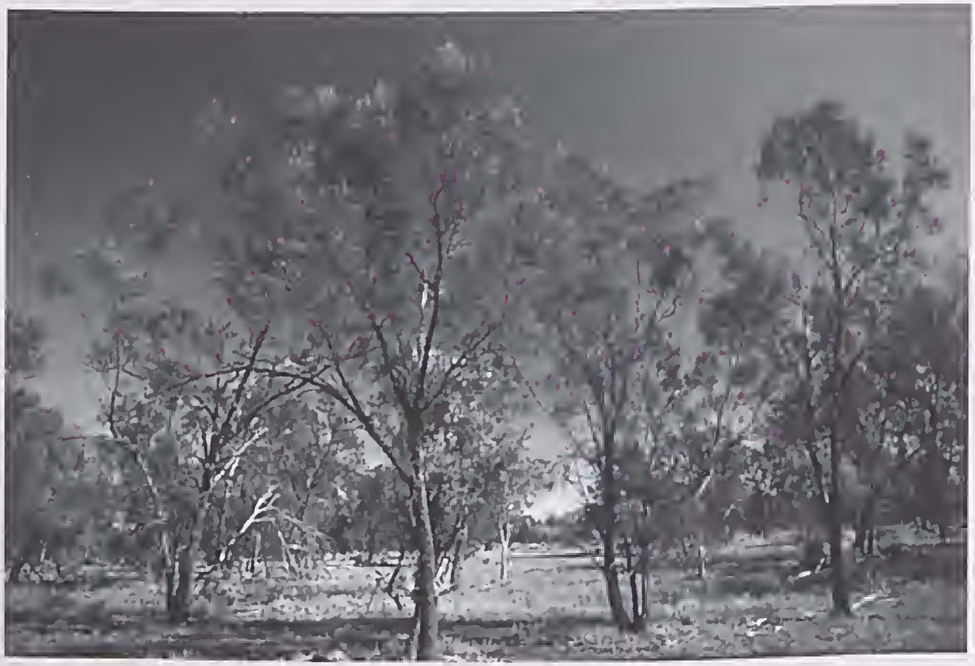

Fig. 9. *Casuarina pauper* trees are a dominant feature of Belah-Rosewood woodland (Community 4) which is distributed widely across the sandplain; site 12 on the Ivanhoe road, east of the Hatfield road.

Notes: Scattered *Flindersia maculosa* and *Acacia loderi* were observed within this community in the far north of the map, representing some of the southern-most populations of these species, which are dominants in communities further north (Pickard & Norris 1994). *Casuarina pauper* also occurs on the lower slopes and surrounding plains of the Manfred Range, a linear series of low rocky outcrops in the far north-east (see Community 29). *Callitris glaucophylla, Hakea leucoptera* and *Hakea tephrosperma* occupy sandier areas of higher elevation within Belah-Rosewood, while *Acacia melvillei* groves occur uncommonly on sandy-loam areas. Mallee may intermix with Belah-Rosewood in deeper sands throughout the mapped area.

The understorey is dominated by chenopod species, usually *Enchylaena tomentosa, Sclerolaena obliquicuspis, Dissocarpus paradoxus* and *Sclerolaena diacantha. Maireana pyramidata* occurs on the shallower sandplains further east, at the transition zone from alluvial to aeolian landscapes. On more calcareous soils at higher elevations, such as the western margins of dry lakes, *Maireana sedifolia* and *Rhagodia ulicina* dominate the understorey, replacing *Maireana pyramidata.*

Vegetation community 8: Black Bluebush (Fig. 10)

Structure: chenopod shrubland–sparse chenopod shrubland

Sample sites (n = 13): 004, 005, 015, 017, 037, 045, 053, 056, 062, 066, 081, 090, 101

Mean no. native species/site: 13.9 ± 5.4

Mean no. exotic species/site: 2.2 ± 1.9 (13%)

Main species: *Maireana pyramidata* (Black Bluebush)

Associated species: *Dissocarpus paradoxus, Stipa nitida, Sclerolaena brachyptera, Atriplex lindleyi, Nitraria billardierei.*

Other common native species: *Rhagodia spinescens, Sclerolaena obliquicuspis, Sclerolaena patenticuspis, Maireana sedifolia.*

Native species recorded from this community only: *Sclerolaena lanicuspis, Dysphania glomulifera* subsp. *eremaea, Tragus australianus, Zygophyllum glaucum.*

Exotic species: **Medicago polymorpha, *Hordeum leporinum, *Cucumis myriocarpus, *Carrichtera annua, *Heliotropium europaeum, *Medicago minima, *Medicago truncatula, *Salvia verbenaca, *Sonchus asper* subsp. *glaucescens, *Asphodelus fistulosus, *Brassica tournefortii, *Centaurea melitensis, *Hypochaeris radicata, *Lamarckia aurea, *Spergularia rubra, *Xanthium spinosum.*

Landform: Level to undulating sandplains, scalded plains, low sandy rises, lunette remnants.

Soils: Red-brown loams and duplex soils with sandy topsoils and clayey subsoils; calcareous sands and loams.

Distribution: This shrubland community is common throughout the mapped area, particularly in the east at the transition from the aeolian landscape to the alluvial Hay Plain. It also occurs on lunettes and raised, scalded, duplex soil areas adjacent to dry lakes.

Condition: Moderate to severe soil erosion due to rabbit infestation with many bare areas; severe scalding on plains and lunettes; heavily grazed.

Threats and conservation status: Bluebush shrubland communities are poorly conserved in the southern sector of the Western Division, particularly on the Hay Plain (Benson 1988, 1989, 1991). Overgrazing of this habitat has resulted in an increase in scalding and other soil erosion, with subsequent vegetation loss. Some areas of Black Bluebush are conserved within Mungo National Park and in Kinchega National Park further north, but the community is considered inadequately conserved over its range.

Key sites for conservation: Several Black Bluebush sites in the east of the mapped area are part of a more continuous area of the community that extends eastwards onto the Hay Plain and could be targeted for conservation. Sites 004, 037 and 101 were noted as being in good condition at the time of sampling.

Notes: *Maireana pyramidata* usually occurs on sandy soils which are alkaline but contain little lime (Dalton 1988). It is a common species on the veneer of aeolian material that indicates the transition from riverine or lacustrine landforms. Bluebush areas tend to be highly susceptible to rabbit infestation, and hence soil erosion, as the loamy soils are ideal for burrowing. *Maireana pyramidata* is a common understorey species to Belah-Rosewood further east, particularly on the Hay Plain. It is often found with *Maireana sedifolia* within the mapped area, and also surrounding low-lying areas of *Atriplex nummularia* (Old Man Saltbush) in the east.

Vegetation community 8p: Pearl and Black Bluebush

Structure: chenopod shrubland–chenopod shrubland

Sample sites (n = 3): 069, 096, 103

Mean no. native species/site: 10.0 ± 2.0

Mean no. exotic species/site: 1.0 ± 1.0 (9%)

Main species: *Maireana sedifolia* (Pearl Bluebush), *Maireana pyramidata* (Black Bluebush)

Associated species: *Dissocarpus paradoxus, Sclerolaena brachyptera, Stipa nitida, Enneapogon avenaceus.*

Other common native species: *Rhagodia ulicina*

Native species recorded from this community only: *Rhodanthe pygmaea*

Exotic species: **Cucumis myriocarpus, *Hordeum leporinum, *Medicago polymorpha.*

Landform: Level to undulating sandplains, scalded plains, low sandy rises, lunette remnants.

Soils: Calcareous red-brown loamy soils. Soil calcareousness determines the distribution of *Maireana pyramidata* and *Maireana sedifolia*. *M. pyramidata* (Black Bluebush) dominates where limestone lies at a depth of 1.2 m or more below the soil surface while soils containing shallower limestone will also support *M. sedifolia* (Pearl Bluebush). Pearl Bluebush tends to occur on calcareous soils where limestone nodules lie within 60 cm of the surface and dominates where limestone exists within the first 30 cm (Beadle 1948).

Distribution: This shrubland community is uncommon throughout the mapped area, and occurs patchily in the east to south-east, and on lunette remnants of the Willandra Lakes.

Condition: Moderate to severe soil erosion due to rabbit infestation with many bare areas; severe scalding on plains and lunettes; severe gully erosion on lunettes; heavily grazed.

Threats and conservation status: Pearl Bluebush is considered poorly conserved and vulnerable in western New South Wales (Benson 1989, Morgan & Terrey 1992). Some areas of Pearl Bluebush are protected in Mungo National Park. Threats and conservation status as for Black Bluebush (8).

Key sites for conservation: As *Maireana sedifolia* is not common across the mapped area the species should be preserved wherever it occurs. Site 046 is a notable site on the western edge of Chibnalwood Lakes, lying within an area of Belah-Rosewood woodland with an unusual *Maireana sedifolia* and *Rhagodia ulicina* understorey.

Notes: *Maireana sedifolia* becomes the dominant Bluebush species further west on the Nullarbor Plain, where calcareous earths are more common (Beard 1990). In western New South Wales it often occurs as an understorey species in Belah-Rosewood communities, particularly on the sandplains further east of the mapped area on the Hay Plain. Associated species such as *Enneapogon avenaceus* and *Rhagodia ulicina* are common on alkaline or calcareous soils (Cunningham et al. 1981).

Vegetation community 11: Bladder Saltbush (Fig. 11)

Structure: chenopod shrubland - open chenopod shrubland

Sample sites (n = 5): 002, 016, 041, 048, 067

Mean no. native species/site: 11.8 ± 6.6

Mean no. exotic species/site: 0.8 ± 0.4 (8%)**Main species:** *Atriplex vesicaria* (Bladder Saltbush). Subspecies as recognised by Harden (1990-93) have not been identified in this survey.

Associated species: *Sclerolaena brachyptera, Disphyma crassifolium* subsp. *clavellatum, Sclerolaena tricuspis, Sclerostegia tenuis, Osteocarpum acropterum* var. *deminuta, Dissocarpus paradoxus.*

Other common native species: *Dissocarpus biflorus* var. *biflorus, Malacocera tricornis, Minuria cunninghamii, Nitraria billardierei, Atriplex lindleyi, Sclerolaena divaricata, Sclerolaena intricata, Sclerolaena muricata* var. *muricata.*

Native species recorded from this community only: *Alternanthera denticulata, Cynodon dactylon, Sigesbeckia orientalis* subsp. *orientalis.*

Exotic species: **Medicago polymorpha, *Hordeum leporinum, *Medicago praecox.*

Landform: Dry lake beds and level to depressed alluvial plains.

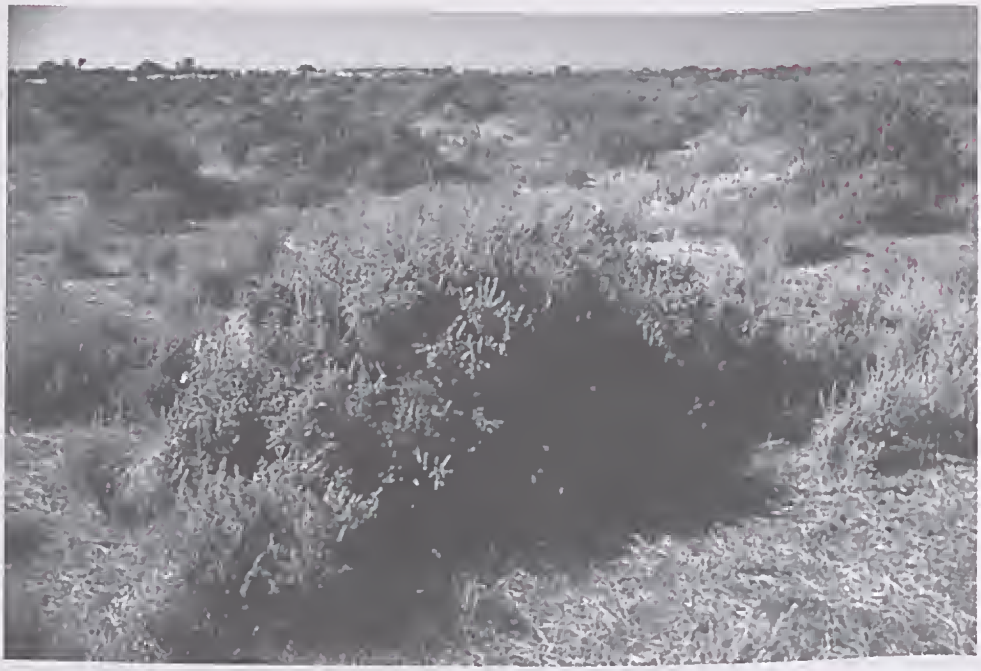

Fig. 10. *Maireana pyramidata* in Black Bluebush chenopod shrubland (Community 8); site 5 on the Ivanhoe road.

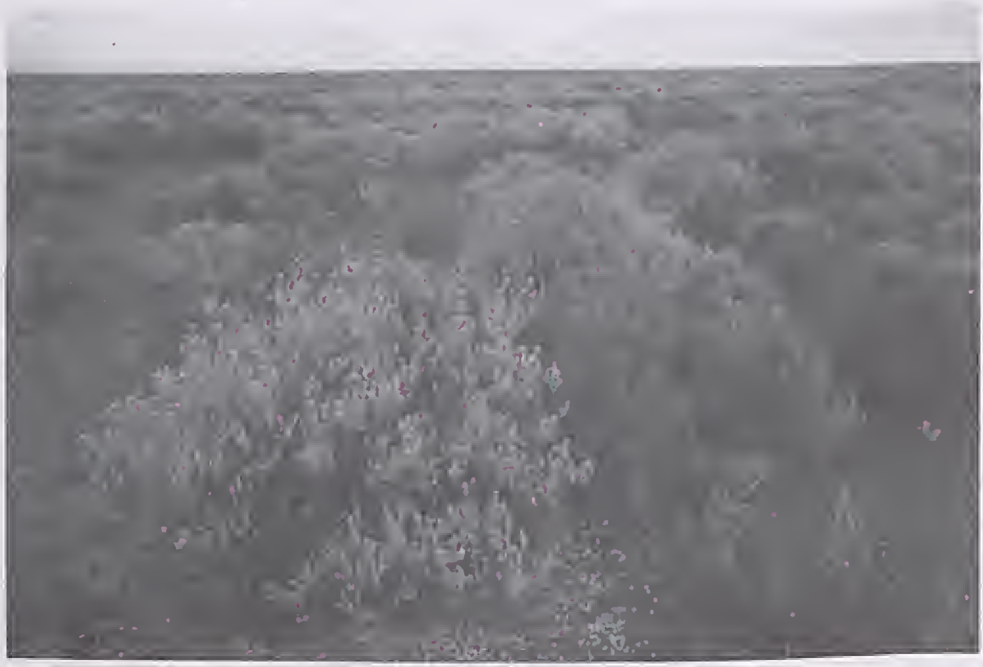

Fig. 11. *Atriplex vesicaria* in Bladder Saltbush shrubland (Community 11); site 41 on the Mildura road.

Soils: Deep, grey, self-mulching and cracking clays to red clay-loam; grey clays and clay-loams to sandy loams overlying clay (Knowles & Condon 1951).

Distribution: *Atriplex vesicaria* shrubland occurs on the alluvial plains in the far south-east of the map sheet area, and in isolated shallow depressions and dry lake beds throughout. Relatively dense stands occur in Lake Mungo within Mungo National Park. The community is no longer intact within the other dry lake beds of the Willandra Lakes system due to overgrazing and clearing.

Bladder saltbush shrubland is most extensive on the Hay Plain east to south-east of the present study area (Porteners 1993). Stands extend east and south from Hatfield, with some smaller areas of the community occurring further west in depressions and on some of the relict lakes of the Willandra Lakes system.

Condition: Previously affected by widespread dieback, presently drought-stressed; moderately to heavily grazed; shrub densities reduced and many areas degraded to copperburr (*Sclerolaena* spp.) shrublands, especially within dry lakes.

Threats and conservation status: The community is considered poorly conserved and vulnerable (Benson 1990). Grazing has drastically affected abundance and altered composition. Mungo National Park contains some good stands of Bladder Saltbush.

Key sites for conservation: Remaining stands of *Atriplex vesicaria* in good condition should be protected in far south-western New South Wales, particularly within dry lakes and depressions as these have been extensively cleared and cropped. Site 041 in the south-east of the study area contains such a stand in good condition.

Notes: Evidence suggests that *Atriplex vesicaria* was recently once more common in the dry lake beds and depressions of the Willandra Lakes (Beadle 1948). The area of Bladder Saltbush has also declined further east on the riverine plain, with overgrazing, drought and dieback events. The area originally occupied by Bladder Saltbush on the riverine plain was estimated at approximately 1.1 million hectares. This decreased to 0.5 million hectares by the end of 1983 after several major dieback events between 1877 and 1983 (Knowles & Condon 1951, Clift et al. 1987, Clift et al. 1989, Semple & Eldridge 1989). In many cases it has been replaced by *Maireana aphylla*, *Sclerolaena* spp., annual saltbush species and introduced grasses. Within the Willandra Lakes area it has been replaced by *Nitraria billardierei*, *Dissocarpus paradoxus*, *Sclerolaena tricuspis*, *Sclerolaena divaricata*, *Sclerolaena intricata*, *Sclerolaena muricata* and *Salsola kali*, species typical of Disturbed Shrubland Complex (22). Degraded communities within Bladder Saltbush shrubland as listed by Beadle (1948) include *Maireana aphylla*, *Atriplex lindleyi*, *Sclerolaena muricata*, annuals and *Nitraria billardierei*.

A species closely associated with *Atriplex vesicaria* is *Sclerostegia tenuis*, which replaces the former in depressed, saline situations (see Community 12). Patches of *Eragrostis australasica* often occur in depressions within both these shrubland communities. In the south-east of the map at the transition from the alluvial Hay Plain to aeolian dune country, Bluebush rises often grade into Bladder Saltbush shrubland at lower levels. *Atriplex vesicaria* often occurs mixed with *Atriplex nummularia* on flat to low-lying sites (see Community 19).

Vegetation community 12: *Sclerostegia tenuis* (Fig. 12)

Structure: closed–open chenopod shrubland

Sample sites (n = 2): 093, 104

Mean no. native species/site: 8.0 ± 0

Mean no. exotic species/site: 0.5 ± 0.7 (6%)

Main species: *Sclerostegia tenuis* (Slender Glasswort), *Disphyma crassifolium* subsp. *clavellatum* (Round-leaf Pigface).

Associated species: *Atriplex vesicaria, Eragrostis australasica, Atriplex lindleyi, Sclerolaena divaricata, Sclerolaena tricuspis, Sclerolaena muricata* var. *muricata.*

Other common native species: *Osteocarpum acropterum* var. *deminuta, Sclerolaena brachyptera.*

Native species recorded from this community only: *Portulaca oleracea.*

Exotic species: **Lamarckia aurea.*

Landform: Saline flats and depressions, depressed alluvial plains.

Soils: Clay soils in saline situations.

Distribution: Occurs in scattered localities within depressed saline flats in the south-east of the mapped area and in the Willandra Lakes region.

Condition: Drought-affected; moderately to heavily grazed; little regeneration.

Threats and conservation status: Not conserved and vulnerable to dieback. Also threatened by grazing and trampling by stock.

Key sites for conservation: Remaining sites of *Sclerostegia tenuis* located within the study area are of very poor condition.

Notes: *Sclerostegia tenuis* often occurs with Bladder Saltbush and dominates in more saline situations. The community is more common further west on the lower alluvium around Lake Victoria and on other dry lakes and saltpans in the area (Fox 1991). It is considered a highly salt-tolerant species, being capable of colonising highly saline environments where no other species will grow (Beadle 1948).

Vegetation community 13: Canegrass (Fig. 13)

Structure: tussock grassland

Sample sites (n = 3): 028, 082, 107

Mean no. native species/site: 9.0 ± 9.5

Mean no. exotic species/site: 1.3 ± 2.3 (13%)

Main species: *Eragrostis australasica* (Canegrass)

Associated species: *Sclerolaena tricuspis*

Other common native species: *Maireana microcarpa, Muehlenbeckia florulenta, Sclerolaena muricata* var. *muricata, Sclerostegia tenuis.*

Native species recorded from this community only: *Amaranthus grandiflorus, Leucochrysum molle, Lepidium pseudohyssopifolium, Maireana microcarpa.*

Exotic species: **Erodium cicutarium, *Hordeum leporinum, *Malva parviflora, *Medicago polymorpha.*

Landform: Swamps, table drains, claypans, alluvial plains with depressions and other low-lying areas subject to intermittent flooding or ponding.

Soils: Slightly saline, compact, heavy grey clays.

Distribution: *Eragrostis australasica* occurs in saline depressions at scattered localities throughout the mapped area.

Condition: Areas cleared, burned and degraded to copperburr (*Sclerolaena* spp.) shrublands; prone to weed infestation.

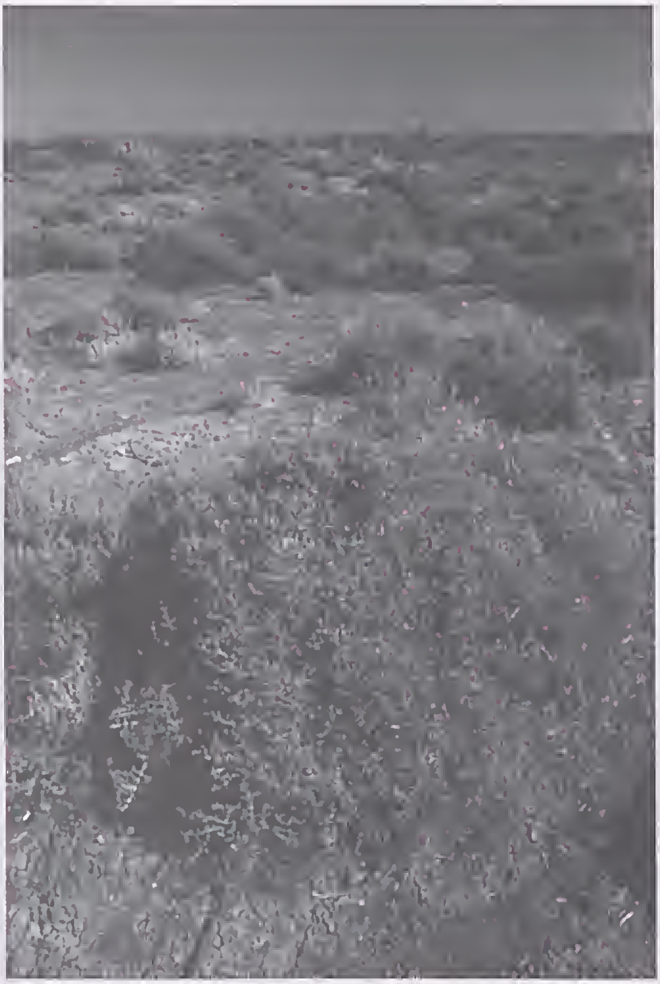

Fig. 12. *Sclerostegia tenuis* shrubland (Community 12) grows in saline flats and depressions; site 67, south-east of Hatfield.

Threats and conservation status: The major threat to this community is dryland cropping with canegrass areas regularly burned and cleared. Swamps are also occupied by feral pig populations which trample, dig up and overgraze the vegetation. The community is inadequately conserved and vulnerable.

Key sites for conservation: Gunnaramby swamp in the far north-east of the study area is an interesting wetland site that contains areas of canegrass. Few other sites in the area have conservation potential. Protection of billabong areas along the Darling River would conserve some canegrass populations.

Notes: *Eragrostis australasica* tolerates regular, but not prolonged flooding, while *Muehlenbeckia florulenta* (Lignum) occupies the wetter areas. It often occurs in depressions within *Atriplex vesicaria, Atriplex nummularia* and *Sclerostegia tenuis.* Many Canegrass swamps were not mapped at the published scale due to their small size.

Vegetation community 16: *Callitris* Woodland (Fig. 14)

Structure: woodland–isolated clumps

Sample sites (n = 5): 007, 050, 083, 086, 092

Mean no. native species/site: 9.6 ± 3.2

Mean no. exotic species/site: 4.8 ± 2.5 (33%)

Main species: *Callitris glaucophylla* (White Cypress Pine)

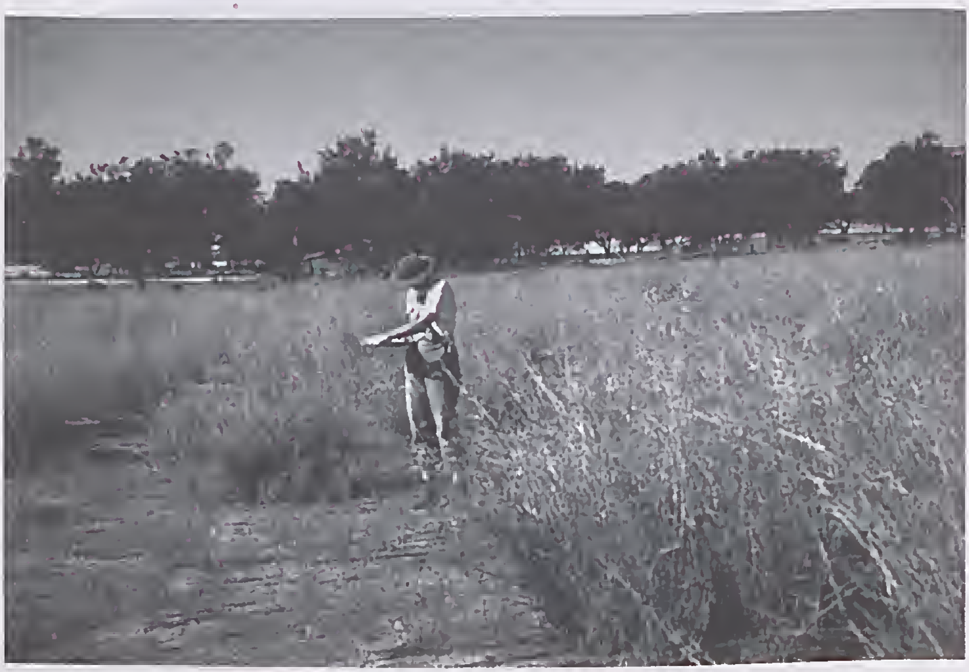

Fig. 13 Canegrass swamps (Community 13) occur in low-lying areas subject to intermittent flooding and ponding; site 28 at Pambra Tank, north-east of Pooncarie.

Associated species: *Enchylaena tomentosa, Salsola kali, Chenopodium cristatum.*

Other common native species: *Alectryon oleifolius* subsp. *canescens, Dissocarpus paradoxus, Erodium crinitum, Nicotiana velutina, Casuarina pauper, Maireana brevifolia, Maireana pyramidata, Sclerolaena diacantha, Sclerolaena obliquicuspis, Solanum esuriale.*

Native species recorded from this community only: *Actinobole uliginosum, Crassula colorata* var. *acuminata, Rhodanthe moschata, Wurmbea dioica* subsp. *dioica, Acacia salicina, Callitris gracilis* subsp. *murrayensis, Scleranthus minisculus, Wahlenbergia gracilenta.*

Exotic species: **Cucumis myriocarpus, *Asphodelus fistulosus, *Brassica tournefortii, *Chenopodium murale, *Heliotropium europaeum, *Hordeum leporinum, *Alopecurus geniculatus, *Avena fatua, *Echium plantagineum, *Hypochaeris glabra, *Malva parviflora, *Marrubium vulgare, *Medicago minima, *Medicago truncatula, *Nicotiana glauca, *Sonchus oleraceus, *Urtica urens, *Vulpia myuros.*

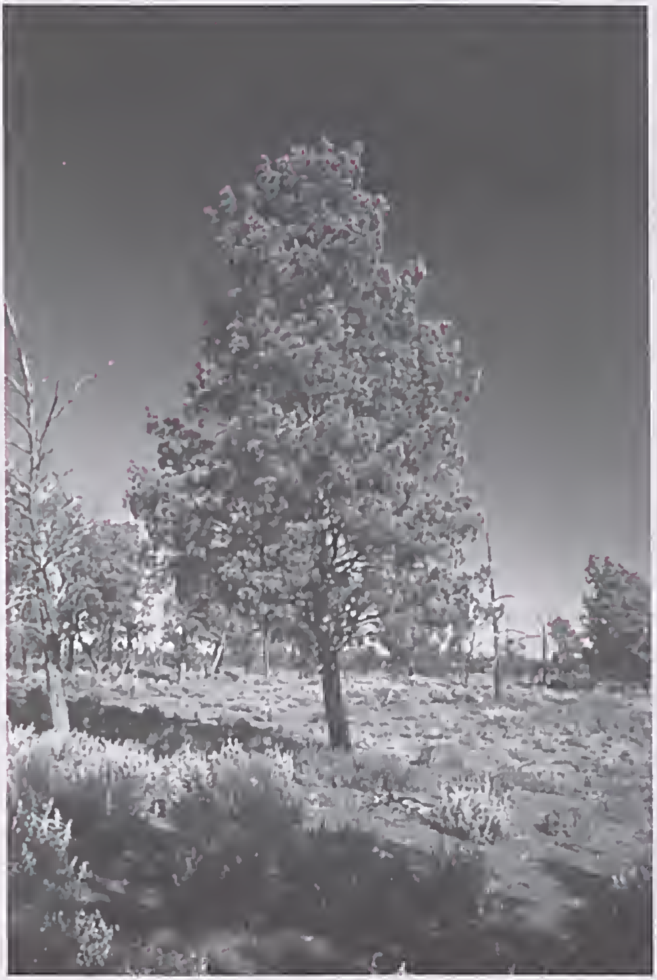

Fig. 14. *Callitris glaucophylla* woodland (Community 16); site 7 on Gol Gol road.

Landform: Raised sandy areas such as low linear dunes, sandhills and ridges.

Soils: Sandy soils; coarse-textured red and brown earths; red-brown sandy-loams.

Distribution: Isolated sandhills with *Callitris* Woodland occur throughout the mapped area, particularly within Belah-Rosewood sandplain areas. The largest area of *Callitris glaucophylla* occurs east of 'Mandleman' and south-east of Mulurulu Lake on a long, continuous sandy ridge extending several kilometres.

Condition: Usually very poor; severe rabbit infestation and scalding; many areas cleared; trees generally thinned; areas of woody shrubs present; few areas with intact shrubby understoreys; little regeneration due to grazing stock and rabbits; prone to weed infestation.

Threats and conservation status: Native Pine communities are amongst the most threatened and vulnerable in western New South Wales, particularly populations of *Callitris verrucosa* (Mallee Cypress Pine) and *Callitris gracilis* subsp. *murrayensis* (Murray Cypress Pine). *Callitris* communities suffer from major clearing and alteration of the understorey, little regeneration and having an older age class over much of their distribution. Rabbit invasion and overgrazing are serious and current threats.

The community is considered endangered in the area and is not conserved. Its relative rarity within the region and the degraded state of remnants gives *Callitris* woodland particular conservation significance. Populations should be protected wherever possible.

Key sites for conservation: Several sites exist within the area that should be targeted for conservation management. Of particular interest is a sandy ridge east of 'Mandleman' which supports a large continuous population of *Callitris glaucophylla* (Site 050). However, much of the vegetation is in poor condition with little regeneration observed. Good stands also exist on the eastern lunette of Lake Garnpung (Site 007).

Notes: Extensive stands of *Callitris glaucophylla* occur further east of the mapped area, extending from Queensland, throughout the slopes and plains of New South Wales, to Victoria. Associated species vary throughout its range. Much of the original understorey has been grazed out but it is thought that common understorey shrubs may have included species of *Dodonaea, Pimelea, Rhagodia, Exocarpos* and *Senna* (Noble & Mulham 1980). Generally the ground cover consists of scattered chenopod shrubs and short-lived grasses and herbs, many of them introduced species. The sandy soils are highly prone to wind erosion and degradation by rabbits. Woody species such as *Dodonaea viscosa* subsp. *angustissima, Eremophila sturtii* and *Senna* species can form dense, low, monospecific scrubs within this community across the mapped area.

Isolated, highly eroded rises carrying *Callitris glaucophylla* occur on the Darling floodplain in the far west of the mapped area. These elevated areas of brown solonised soils which are not subject to flooding, also carry open or scattered *Acacia victoriae*, sometimes with *Eremophila sturtii* (Turpentine), *Dodonaea* spp. (Hopbushes), and Belah-Rosewood (Stannard 1963). Several groves of *Callitris gracilis* subsp. *murrayensis* (Murray Cypress Pine) occur on sandy ridges on the western margin of Lake Mungo and comprise large, old trees.

Callitris Woodland is one of the more vulnerable vegetation types in far-western New South Wales in the context of present land use. It is under serious threat from rabbits and stock with even-aged, often old stands of trees dying out. The coarse-textured soils are susceptible to rabbit infestation, resulting in massive erosion and scalding, and regeneration is prevented due to the grazing out of seedlings. Populations should be preserved wherever possible.

Vegetation community 17: *Acacia melvillei* Woodland (Fig. 15)

Structure: isolated trees–open woodland

Sample sites (n = 2): 059, 085

Mean no. native species/site: 13.5 ± 6.4

Mean no. exotic species/site: 1.5 ± 0.7(10%)

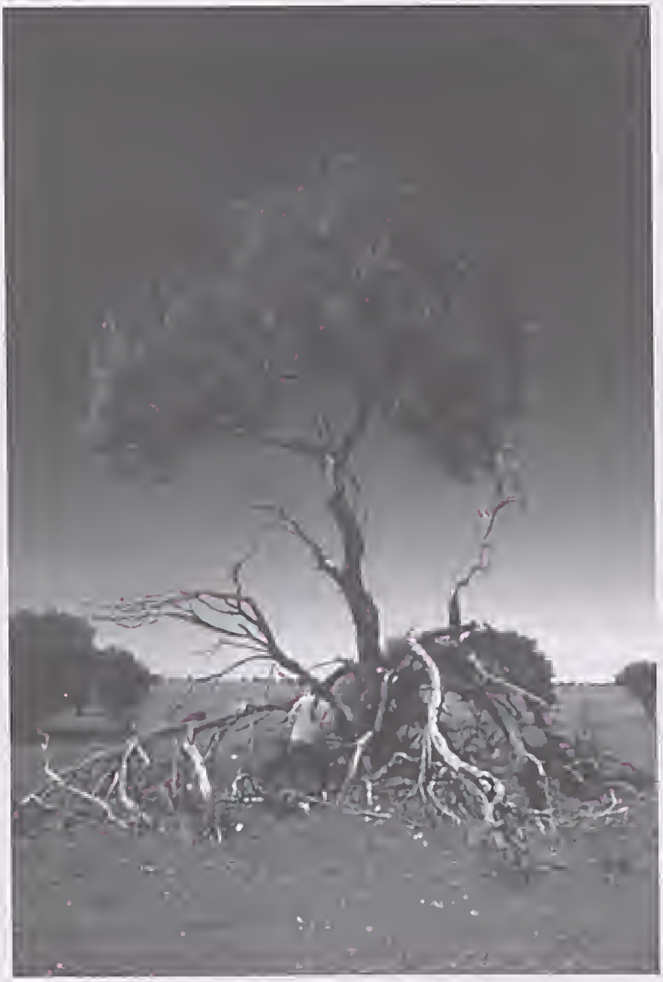

Fig 15. *Acacia melvillei* woodland (Community 17) occurs as isolated trees. Many specimens are senescing with no sign of regeneration; site 59 on the Ivanhoe to Mulurulu road.

Main species: *Acacia melvillei* (Yarran)

Associated species: *Dissocarpus paradoxa, Enchylaena tomentosa, Sclerolaena obliquicuspis, Eremophila sturtii, Stipa nitida.*

Other common native species: *Acacia homalophylla, Sclerolaena diacantha.*

Native species recorded from this community only: *Acacia homalophylla, Ixiolaena tomentosa, Lycium australe.*

Exotic species: **Salvia verbenaca, *Asphodelus fistulosus, *Medicago polymorpha.*

Landform: Level to undulating sandplains.

Soils: Red-brown sandy loam soil; reddish loam flats.

Distribution: Only a few small remnant areas of *Acacia melvillei* occur on the Pooncarie map area. *Acacia melvillei* can occur as groves or small local communities within *Callitris* Woodland (Community 16) and Belah-Rosewood (Community 4).

Condition: Severe scalding and rabbit infestation; most sites heavily grazed; understorey absent or degraded; many areas cleared; some large, old trees present; areas of woody shrubs present.

Threats and conservation status: *Acacia melvillei* woodland is regarded as a highly vulnerable vegetation community which is also unconserved. Inland *Acacia* communities are considered one of the groups with the poorest conservation status in New South Wales (Benson 1989). Immediate threats are grazing by stock and rabbits, resulting in scalding and little or no regeneration of the community. Seedling establishment of *Acacia melvillei* is strongly limited by rabbit browsing and protecting existing populations will require strict rabbit control (Batty & Parsons 1992). Stock grazing pressure is also a threat to regeneration. Profuse root suckering of *Acacia melvillei* can result from root damage by cultivation in dryland cropping areas.

Key sites for conservation: *Acacia melvillei* populations should be protected and conserved wherever found, including sites 059 and 085 within the mapped area. Some excellent stands which should also be targeted for conservation action exist further south around Balranald (Scott 1992).

Notes: This community is very small in extent and forms localised stands in Belah-Rosewood and *Callitris* Woodlands. Only three very open areas have been mapped, all in the north-east of the map area. *Acacia melvillei* is often mistaken for the very similar *Acacia homalophylla*, and the two species often occur together. The community is more extensive, although not common, on the plains and slopes further east.

Vegetation community 18: Lignum and Nitre Goosefoot

Structure: open–closed shrubland

Sample sites (n = 3): 029, 035, 108

Mean no. native species/site: 8.3 ± 2.1

Mean no. exotic species/site: 2.0 ± 0 (20%)

Main species: *Muehlenbeckia florulenta* (Lignum), *Chenopodium nitrariaceum* (Nitre Goosefoot).

Associated species: *Salsola kali, Sclerolaena muricata* var. *muricata, Teucrium racemosum, Marsilea drummondii.*

Other common native species: *Eragrostis australasica*

Native species recorded from this community only: *Amaranthus macrocarpus* var. *macrocarpus, Polygonum plebeium, Senecio runcinifolius.*

Exotic species: **Hordeum leporinum, *Heliotropium supinum, *Medicago polymorpha, *Xanthium spinosum, *Tribulus terrestris, *Verbena officinalis.*

Landform: Intermittently flooded depressions, channels, river-flats and swamps. Flooding is relatively infrequent, but often prolonged.

Soils: Heavy grey to grey-brown cracking clays.

Distribution: This community occurs infrequently throughout the mapped region, in swamps adjacent to the Darling River and Willandra Creek systems and in scattered low-lying depressions.

Condition: Weed infestation; grazed by cattle; swamps used as habitat by feral pigs.

Threats and conservation status: This community is considered poorly conserved. There are no significant stands of Lignum conserved in south-western New South Wales (Benson 1988). It is threatened with clearing for dryland and irrigated cropping and disruption of natural flooding regimes by river regulation.

Key sites for conservation: Conservation of Riverine Forest areas along the Darling River would preserve associated Lignum and *Chenopodium nitrariaceum* understoreys. Gunnaramby Swamp in the north-east of the mapped area also contains significant areas of Lignum which are worth protecting. Some pig control is desirable in swamps across the mapped area.

Notes: *Chenopodium nitrariaceum* exceeds Lignum as the dominant species in this community in occasionally inundated areas with less restricted drainage. It is a common understorey shrub in Riverine Forest and Black Box communities and a common associate species of *Atriplex nummularia* (Old Man Saltbush). *Muehlenbeckia florulenta* can withstand more prolonged flooding, favouring channelled plains and depressions with impeded drainage, and nearly always occurs with *Chenopodium nitrariaceum.*

Vegetation community 19: Old Man Saltbush (Fig. 16)

Structure: chenopod shrubland–open chenopod shrubland

Sample sites (n = 4): 038, 065, 068, 102

Mean no. native species/site: 12.0 ± 4.7

Mean no. exotic species/site: 3.3 ± 2.1 (20%)

Main species: *Atriplex nummularia* (Old Man Saltbush)

Associated species: *Maireana pyramidata, Atriplex lindleyi, Osteocarpum acropterum* var. *deminuta*.

Other common native species: *Chenopodium nitrariaceum, Einadia nutans* subsp. *nutans, Rhagodia spinescens, Salsola kali, Sclerolaena divaricata, Sclerostegia tenuis, Atriplex vesicaria, Sclerolaena tricuspis.*

Native species recorded from this community only: *Pratia concolor.*

Exotic species: **Xanthium spinosum, *Medicago polymorpha, *Heliotropium europaeum, *Centaurea melitensis, *Cucumis myriocarpus, *Hordeum leporinum, *Lamarckia aurea, *Lycium ferocissimum, *Marrubium vulgare, *Sonchus oleraceus, *Verbena officinalis.*

Landform: Level to depressed plains, low-lying areas and depressions.

Soils: Grey-brown loams to grey and brown cracking clays.

Distribution: This community occurs in scattered localities in the east to south-east of the mapped area.

Condition: Largely cleared; heavily grazed with shrubs thinned; some scalding in open areas; little regeneration due to grazing stock, rabbits, goats and kangaroos; some weed and copperburr (*Sclerolaena* spp.) infestation.

Threats and conservation status: This community has an extremely poor conservation status and is extinct in some regions and rare overall (Benson 1989). Grazing, clearing, rabbit infestation and mismanagement of remnants are the current threats.

Key sites for conservation: *Atriplex nummularia* should be protected wherever it occurs. The community is now very rare in the mapped area, and remnants, although highly disturbed, should be fenced-off from stock with rabbit control.

Notes: Old Man Saltbush remnants have been subjected to grazing pressure, rabbit-disturbance and clearing. Larger remnant areas are delineated on the maps but many smaller patches exist, especially around homesteads and in holding paddocks, often consisting of only scattered individuals. The shrub is palatable to both stock and rabbits and does not recover well with constant defoliation under heavy grazing pressure (Cunningham et al. 1981).

Vegetation community 22: Disturbed Shrubland Complex (Fig. 17)

Structure: shrubland or chenopod shrubland–sparse shrubland or sparse chenopod shrubland

Sample sites (n = 6): 006, 031, 036, 095, 100, 109

Mean no. native species/site: 11.7 ± 2.5

Mean no. exotic species/site: 2.5 ± 2.8 (20%)

Main species: *Dissocarpus paradoxus* (Cannonball Burr), *Nitraria billardierei* (Dillon Bush).

Associated species: *Maireana aphylla, Sclerolaena tricuspis, Salsola kali, Atriplex lindleyi, Euphorbia planiticola, Atriplex holocarpa, Chamaesyce* species B, *Panicum decompositum.*

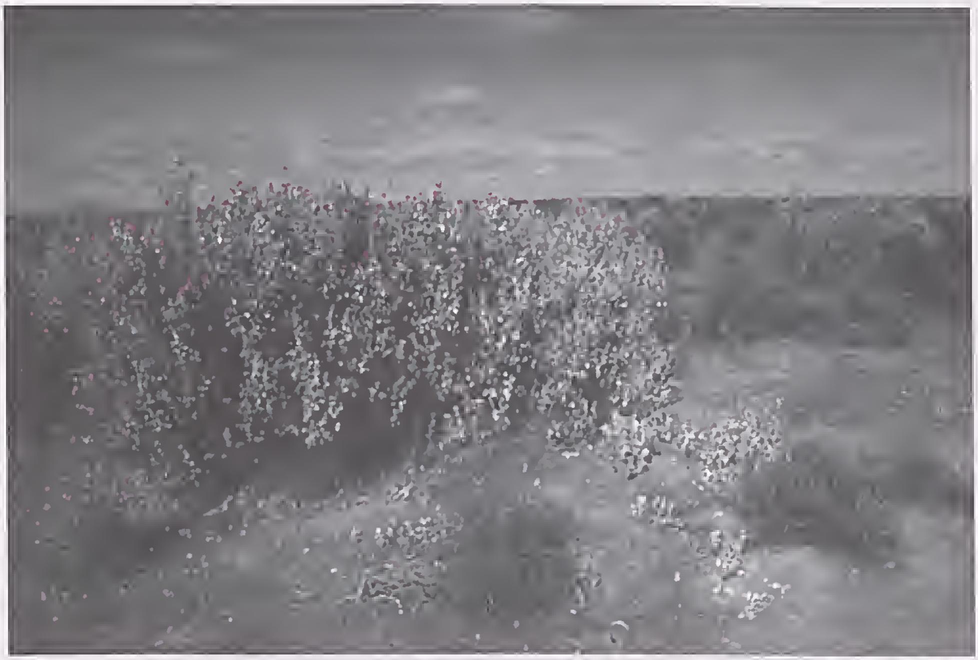

Fig. 16. *Atriplex nummularia* in Old Man Saltbush chenopod shrubland (Community 19); site 65 on the Turlee to Balranald road, south-west of Hatfield.

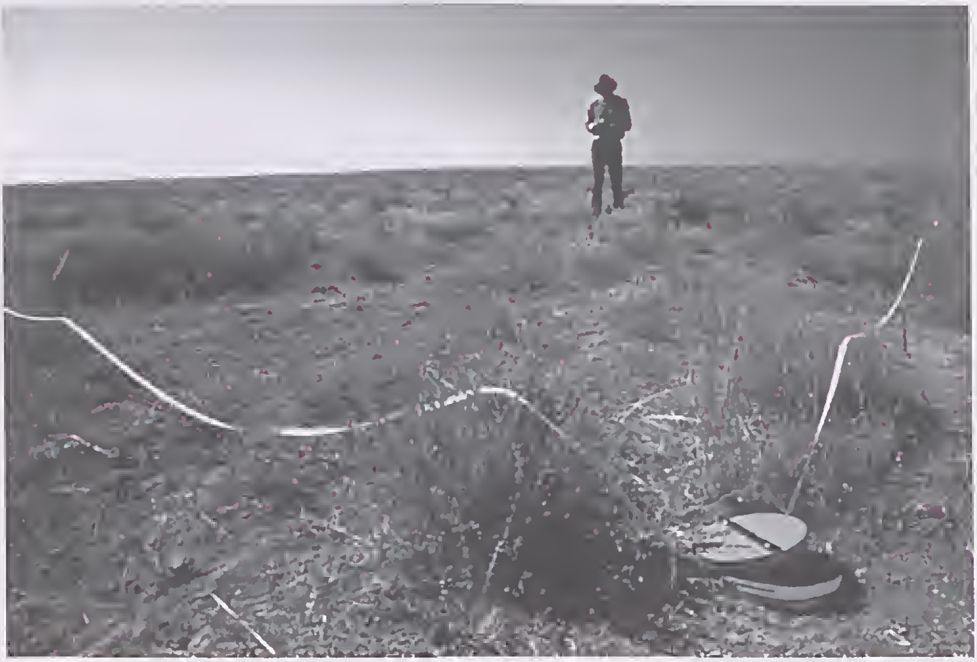

Fig. 17. In highly disturbed areas, a complex of shrubs will prevail (Community 22); site 6 on Garnpung Lake.

Other common native species: *Danthonia caespitosa, Osteocarpum acropterum* var. *deminuta, Sclerolaena brachyptera,* occasionally remnant *Atriplex vesicaria, Neobassia proceriflora, Sclerolaena divaricata, Sclerolaena intricata, Sclerolaena muricata.* This community occupies disturbed areas and usually comprises a high proportion of introduced and annual species. Other common native species vary depending on the composition of the original vegetation.

Native species recorded from this community only: *Atriplex intermedia, Brachycome heterodonta* var. *heterodonta, Homopholis proluta, Maireana aphylla, Neobassia proceriflora, Panicum laevinode, Vittadinia pterochaeta.*

Exotic species: **Cucumis myriocarpus, *Hordeum leporinum, *Tribulus terrestris, *Hibiscus trionum, *Medicago minima, *Carrichtera annua, *Erodium cicutarium, *Medicago truncatula, *Sonchus asper* subsp. *glaucescens.*

Landform: Disturbed low-lying alluvial plains, floodplains and dry lakebeds.

Soils: Grey to grey-brown clay and loam soils, often saline.

Distribution: This disturbed shrubland predominates on the previously cropped and/or heavily grazed lake beds of the Willandra Lakes system, and also occurs in scattered depressions and dry lakes throughout the mapped area.

Condition: Heavily grazed; occurs on previously cropped, cleared and overgrazed landscapes; overall increase in range and populations; moderate to severe scalding and other soil erosion; provides shelter and habitat for rabbits.

Threats and conservation status: This community is not considered threatened and its distribution is actually increasing as it establishes in disturbed areas once occupied by other chenopod shrublands.

Notes: *Nitraria billardierei* tends to occur in areas of high grazing pressure and in previously cropped areas. Its distribution has increased markedly with the changed land use in the area since European settlement, and severe overgrazing has resulted in the establishment of Dillon Bush in areas once occupied by *Atriplex vesicaria* and *Atriplex nummularia* (Noble & Whalley 1978). Dillon Bush commonly occurs within other chenopod shrubland communities.

Dissocarpus paradoxus is a dominant understorey shrub in most aeolian vegetation communities and a common associate in alluvial communities within the Pooncarie map sheet area. In the present survey it was recorded from every community except Riverine Forest and Rocky Outcrop Woodland Complex, and it occurred in over 50 per cent of sites. It is particularly common in Belah-Rosewood Woodland (4), Sandplain Mallee (3d) and Bluebush shrublands (8 and 8p). Because it increases in overgrazed situations and is often found in abundance to the exclusion of more robust perennial plants, it is regarded as an indicator of poor range condition (Mitchell & Wilcox 1994). Particularly high numbers of rabbits are associated with Dillon Bush on sandy substrates (Fatchen & Fatchen 1989).

Copperburrs (*Sclerolaena* spp.) are also considered weed or increaser species which colonise areas that have been heavily grazed (Cunningham et al. 1981). *Sclerolaena* *tricuspis, Sclerolaena divaricata* and *Sclerolaena muricata* all colonise over-grazed areas, especially those once dominated by *Atriplex vesicaria* (Leigh & Mulham 1965).

Vegetation community 29: Rocky Outcrop Woodland Complex (Fig. 18)

Structure: open woodland to isolated trees

Sample sites (n = 2): 032, 078

Mean no. native species/site: 25.5 ± 2.1

Mean no. exotic species/site: 5.0 ± 4.2 (16%)

Main species: *Callitris glaucophylla* (White Cypress Pine), *Eucalyptus intertexta* (Western Red Box).

Associated species: *Enchylaena tomentosa, Einadia nutans* subsp. *nutans, Sida intricata, Sclerolaena convexula, Solanum ferocissimum, Chamaesyce drummondii, Erodium crinitum, Goodenia fascicularis, Phyllanthus fuernrohrii, Vittadinia gracilis.*

Other common native species: *Acacia aneura, Acacia burkittii, Eriostemon linearis.* Ferns such as *Cheilanthes distans, Cheilanthes lasiophylla, Cheilanthes sieberi* subsp. *sieberi* and *Pleurosorus rutifolius* grow under rocky overhangs and in moist crevices.

Native species recorded from this community only: *Cheilanthes lasiophylla, Phyllanthus fuernrohrii, Solanum ferocissimum, Abutilon fraseri, Abutilon halophilum, Acacia aneura, Acacia burkittii, Cheilanthes distans, Cheilanthes sieberi* subsp. *sieberi,*

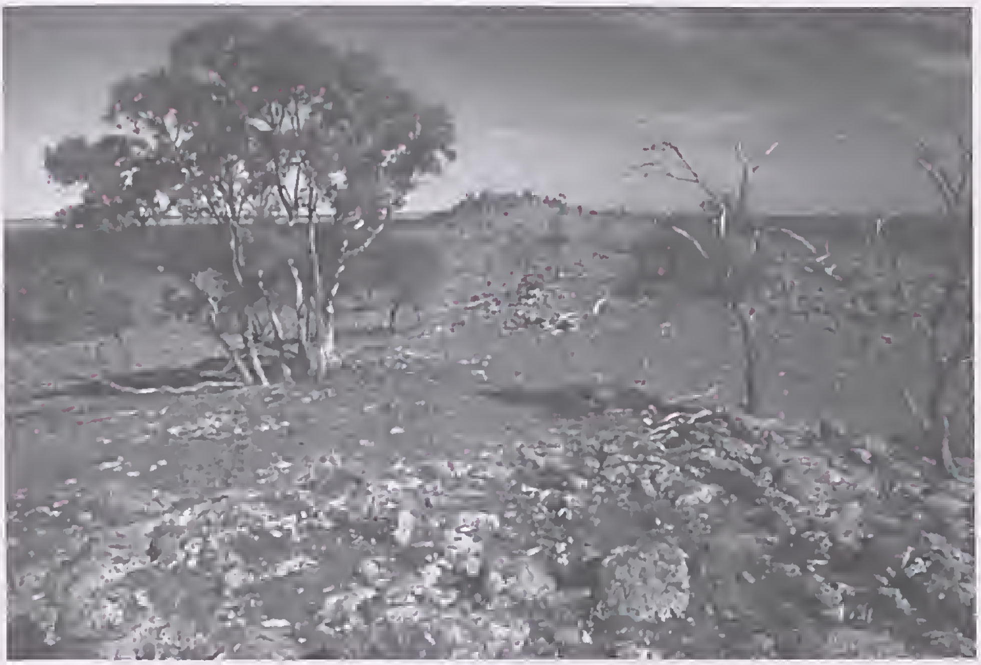

Fig. 18. *Eucalyptus intertexta* is a dominant species of the Rocky Outcrop Woodland Complex (Community 29). As this community is restricted to rocky areas, it is rare on the Pooncarie map; site 32 on Manfred Mountain.

Digitaria brownii, Enteropogon acicularis, Eriostemon linearis, Evolvulus alsinoides var. *decumbens, Glycine canescens, Haloragis odontocarpa, Hibiscus krichauffianus, Pachymitus cardaminoides, Paspalidium constrictum, Pleurosorus rutifolius, Sida cunninghamii, Sigesbeckia australiensis.*

Exotic species: **Asphodelus fistulosus, *Cirsium vulgare, *Cucumis myriocarpus, *Erodium cicutarium, *Hordeum leporinum, *Lamarckia aurea, *Lycium ferocissimum, *Marrubium vulgare, *Medicago minima, *Medicago truncatula, *Salvia verbenaca, *Silene apetala.*

Landform: Footslopes, ridges and crests of low rocky outcrops. Outcropping of quartzite and sandstone, pebbly to conglomeratic in part, siltstone and shale (Norris & Thomas 1991).

Soils: Brown to dark brown sandy loam with surface stones and gravel, overlying a sandstone-conglomerate substrate. Shallow, stony, sandy soils, becoming redder and better developed downslope (Walker 1991). Sandstone lithosols or skeletal soils (which occur where rock is near the surface) comprising shallow sands, loams and clay-loams which are stony or gravelly (Norris & Thomas 1991).

Distribution: Manfred Hill in the Manfred Range, in the far north-east of the Pooncarie map area and south-west of Ivanhoe. This is the only rocky outcrop existing within the mapped area.

Condition: Severe rabbit infestation and grazing and trampling by goats; almost total tree clearing and dieback; high proportion of exotic species.

Threats and conservation status: Rocky outcrops and their associated vegetation are poorly conserved in western New South Wales. Many of these outcrops and ranges are heavily disturbed and represent isolated islands of vegetation amongst tracts of agricultural land. Most are unprotected and, with continued disturbance and the lack of corridors for species dispersal, will continue to degenerate (Norris & Thomas 1991).

Key sites for conservation: Manfred Hill in the north-east of the study area is very degraded but should be protected. The Warranary Range further east on the northern edge of the Hay Plain is a better example of this community and would be well worth targeting for conservation action (Porteners 1993).

Notes: This woodland community is very degraded due to clearing, overgrazing and the proliferation of goats. Few trees remain (scattered *Callitris glaucophylla, Eucalyptus intertexta, Acacia aneura* and *Acacia burkittii*) and the understorey is very sparse, comprising various grazed-down herbs and shrubs. The composition of the understorey and ground cover will vary seasonally. A dense area of *Eriostemon linearis* (Narrow-leaf Waxflower) shrubland was observed growing on a south-west facing slope in the centre of the Manfred Range.

Feral goats are a major problem in rocky areas, causing much damage in high numbers by grazing and trampling native vegetation. Their preferential diet includes a wide range of native species (Norris & Thomas 1991). Rabbits are also a problem in the sandier soils of the footslopes where they undermine root systems and cause massive soil erosion. Goats were observed in large numbers on and around Manfred Hill.

Vegetation community 30: Lunette Shrubland (Fig. 19)

Structure: shrubland–sparse shrubland

Sample sites (n = 3): 049, 058, 089

Mean no. native species/site: 11.7 ± 9.9

Mean no. exotic species/site: 5.3 ± 2.3(29%)

Main species: *Dodonaea viscosa* subsp. *angustissima* (Narrow-leaf Hopbush)

Associated species: *Salsola kali, Stipa nitida, Myriocephalus stuartii.* This community usually comprises a high proportion of introduced and annual species.

Other common native species: *Maireana pyramidata, Acacia ligulata, Pittosporum phylliraeoides.*

Native species recorded from this community only: *Digitaria ammophila, Pimelea trichostachya, Pittosporum phylliraeoides.*

Exotic species: **Asphodelus fistulosus, *Brassica tournefortii, *Bromus rubens, *Chenopodium murale, *Cucumis myriocarpus, *Echium plantagineum, *Hypochaeris glabra, *Hordeum leporinum, *Lamarckia aurea, *Medicago minima, *Medicago polymorpha, *Medicago truncatula, *Nicotiana glauca, *Salvia verbenaca, *Sonchus oleraceus.*

Landform: Lake lunettes, lunette remnants and disturbed areas, usually highly eroded.

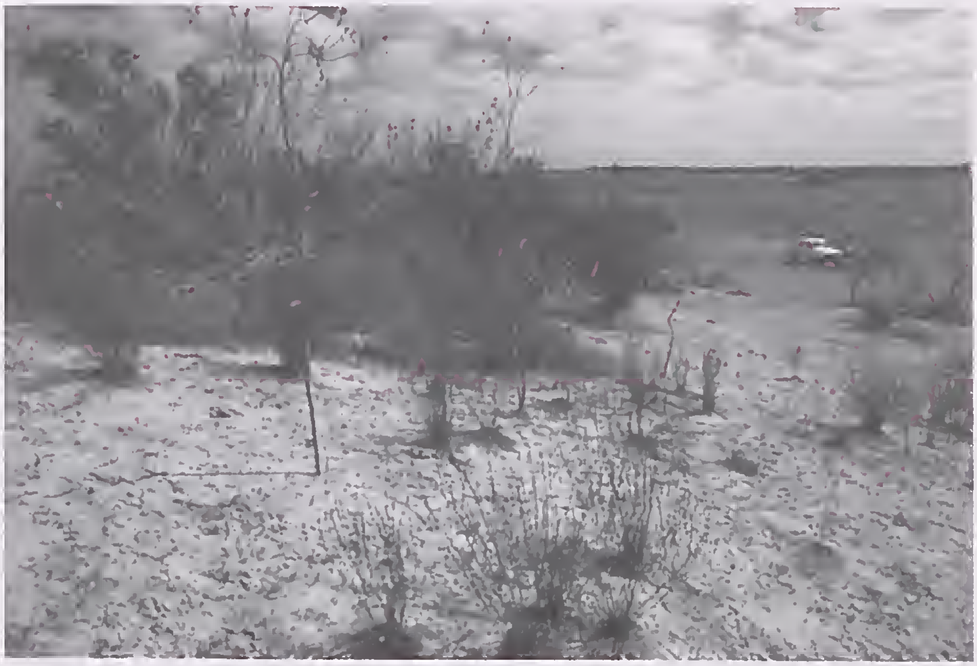

Fig. 19. The sandy lunettes on the lake edges support Lunette Shrubland (Community 30). Its species composition and structure is dependent on its disturbance history; site 58 on the edge of Lake Mulurulu.

Soils: White calcareous sands to light red-brown sandy loam.

Distribution: This community occurs on the crescent-shaped lunettes and patchier lunette remnants on the eastern edges of the large dry lakes in the Willandra Lakes system. The lunettes of Garnpung and Mulurulu Lakes carry dense areas of Hopbush. Hopbush also occurs as localised stands within Belah-Rosewood and Mallee, particularly in cleared areas within these and other sandplain communities.

Condition: Heavily eroded; rabbit infestation; moderately grazed; high proportion of exotic species.

Threats and conservation status: This community is not considered threatened as Hopbush is increasing in range and distribution as regrowth in disturbed areas.

Key sites for conservation: The large lunettes associated with the Willandra Lakes are important, naturally eroding landform features. Their degradation has been accelerated with increased grazing and the introduction of rabbits. As well as having significant archaeological values, they support many important and interesting plant species and sites should be preserved and protected in the area. The huge lunette of Lake Garnpung is of particular interest and management plans should include rabbit control.

Notes: *Dodonaea viscosa* subsp. *angustissima* is a widespread and common woody shrub of the arid, semi arid and tableland zones, often forming dense thickets within disturbed and cleared areas. It is considered a pest species by graziers because its dense regrowth interferes with the grazing potential of the land (Cunningham et al. 1981).

Open areas (OA)

These are highly disturbed areas with a vegetation cover of annual or short-lived perennial grasses, herbs, forbs and few shrubs. Open Areas result from intense grazing, erosion, clearing and fire. Introduced pasture species usually predominate, such as **Hordeum leporinum*, **Lamarckia aurea*, **Bromus rubens*, **Avena fatua* and **Medicago* spp. Native grasses may include *Stipa nitida*, *Enneapogon avenaceus*, *Danthonia caespitosa*, *Dactyloctenium radulans* and *Sporobolus caroli*. The composition of annual herbs changes seasonally but may include **Asphodelus fistulosus*, **Salvia verbenaca*, *Erodium* spp., *Ptilotus* spp., *Swainsona* spp., asteraceaeous herbs and annual saltbushes. Open Areas may also carry outbreaks of Narrow-leaf Hopbush (*Dodonaea viscosa* subsp. *angustissima*) and Turpentine (*Eremophila sturtii*). Weeds often dominate the more disturbed Open Areas such as road verges, table drains and heavily used paddocks.

Bare areas (BA)

These areas are naturally bare of any vegetation and include lake lunettes and other isolated and often shifting dunes. The deep, white, calcareous sands of lunette remnants are highly susceptible to erosion and are often completely open with no vegetation cover. Bare areas are not uncommon in the Willandra Lakes area.

Cleared areas (C)

These areas have been almost entirely cleared of natural vegetation and often cultivated for agricultural purposes. Remnant types are indicated on the vegetation map in brackets after the C symbol.

Floristic composition

A total of 330 species (339 taxa) from 62 families were recorded for the mapped area during the present survey. The number of species recorded for the region rises to 497 (509 taxa) from 75 families if other survey records are included. The record is dominated by species from the Chenopodiaceae (59 species or 18 %), Asteraceae (48 species or 15 %) and Poaceae (32 species or 10 %). As the survey was conducted during a period of drought, many annual and other seasonal species were not recorded, hence the relatively low proportions of annual Asteraceae and Chenopodiaceae. A large proportion of species recorded (12 %) are exotic, and two *Eucalyptus* hybrids were also found. A species list for the mapped area compiled from current and past survey data is given in Appendix 2.

The most frequently recorded native species were *Stipa nitida* (60 sites or 55% of sites), *Dissocarpus paradoxa* (59 sites or 54%), *Enchylaena tomentosa* (48 sites or 44%), *Sclerolaena diacantha* (46 sites or 42%), *Salsola kali* (44 sites or 40%) and *Sclerolaena obliquicuspis* (43 sites or 39%). The most frequently recorded exotic species were **Hordeum leporinum* (21 sites or 19% of sites), **Medicago polymorpha* (17 sites or 16%), **Cucumis myriocarpus* (15 sites or 14%) and **Asphodelus fistulosus* (11 sites or 10%).

The species richness and weediness of each community are summarised in Table 2. The highest number of species (87) was recorded from Black Box Woodland (2), followed by Black Bluebush (8) with 77 species and Dune Mallee (3a and 3b) with 74 species each. The communities with the lowest species counts were *Sclerostegia tenuis* (12) with a total of 15 species, Lignum and *Chenopodium nitrariaceum* (18) with 22 species and *Acacia melvillei* Woodland (17) with 23 species. *Callitris* Woodland (16) recorded the highest proportion of exotic species at 35 per cent, followed by Riverine Forest (1) at 30 per cent and Old Man Saltbush (19) at 24 per cent.

In arid and semi-arid communities the composition and turnover of annual and short-lived perennial species varies from year to year. Many of these species are not specific to particular soil types or communities and are very widespread. Species variability within a community was highest in shrublands of Dillon Bush, Cannonball Burr and Copperburr (22), in which the dominant species vary considerably from site to site. Black Bluebush (8) and Lunette Shrubland (30) also showed high species variability. The most homogeneous communities were the mallee and Belah-Rosewood groups (3a, 3b, 3d and 4) which showed high consistency in both overstorey and understorey species.

Several extensions of range were recorded during the survey for a number of species (Appendix 2). Nine species are new records for the Far South Western Plains botanical subdivision of New South Wales (Harden 1990–93). Species of particular conservation

Table 2. Species richness and weediness per community.

Community	No. Sites	Total Species	Native Species	Exotic Species
1	2	33	23	10 (30%)
2	6	87	73	14 (16%)
3a	16	74	73	1 (1%)
3b	9	74	72	2 (3%)
3d	11	62	55	7 (11%)
4	15	67	65	2 (3%)
8	13	77	62	15 (19%)
8p	3	25	22	3 (12%)
11	5	36	33	3 (8%)
12	2	15	14	1 (7%)
13	3	27	23	4 (15%)
16	5	49	32	17 (35%)
17	2	23	20	3 (13%)
18	3	22	17	5 (23%)
19	4	42	32	10 (24%)
22	6	49	41	8 (16%)
29	2	50	40	10 (20%)
30	3	42	29	13 (16%)

significance recorded within the Pooncarie 1: 250 000 map sheet area are listed in Table 3. Six species recorded for the area are nationally listed as rare or threatened Australian plants (ROTAPs) (Briggs & Leigh 1996), while eight are in the schedules of the NSW Threatened Species Conservation Act. Twenty-five species have restricted distributions in the Western Division of New South Wales (Pressey et al. 1990). Seventy-two are listed as rare or threatened plants in Victoria (Gullan et al. 1990) but many of these are common in New South Wales. Therefore, only the species with the highest risk codes in Victoria — vulnerable, endangered or presumed extinct — are considered here.

Leptorhynchos waitzia appears to be very rare and could be added to the national ROTAP list. Due to drought conditions at the time of the survey, other rare herbaceous species may not have been recorded.

Discussion

Distribution of the vegetation communities

There are five main landforms in the mapped area: dunefields, sandplains, relict lakes, alluvial plains, and hills and footslopes (see Figure 3). The landscape is dominated by the plains and dune systems of the aeolian sandsheets and their characteristic vegetation communities of woodlands and shrublands. The other common landscape feature is the ancient dry lake system and associated lunettes running through the centre of the mapped area. These lacustrine elements principally support shrublands. The riverine plain and its shrublands occupy only a relatively small area in the south-east of the map. The alluvial floodplain associated with the Darling River in the west and the Willandra Creek in the north-east are similarly small in extent, but support forest, woodland and swamp vegetation that are confined to that physiographic element. Similarly, the rocky outcrops of Manfred Hill in the north-east support vegetation unique to that system.

The vegetation patterns observed in the semi-arid regions of south-western New South Wales reflect rainfall and its interactions with soil type and topography. The distribution of plant species has been linked to the distribution of moisture throughout the soil profile (Noy-Meir 1974), which, in turn, is largely determined by soil texture. Soil fertility (as available phosphate and exchangeable calcium) and soil salinity also influence the distribution of vegetation, although to a lesser degree than moisture capacity (Noy-Meir 1974). These soil characteristics are intimately associated with the geomorphology of the landscape.

The deep, red to orange siliceous sands of the dunefields support Irregular Dune Mallee (3a) and Linear Dune Mallee (3b). These woodlands share an understorey dominated by *Triodia scariosa* subsp. *scariosa* and shrubs at various densities. These dunefield mallee systems are spread throughout the map area, but most particularly in a large band from the southwest corner arching across to the central eastern portion. In the level areas between well-spaced dunes, the soil is more calcareous and of a finer grain, similar to the soil types characteristic of the sandplain. Thus, open woodlands of Belah-Rosewood (4) may be found interspersed amongst the dunefield mallee communities.

The calcareous loamy sands and red-brown earths of the sandplain commonly contain Belah-Rosewood open woodland (4), Sandplain Mallee (3d) and Bluebush shrublands (8 and 8p). *Callitris* open woodland (16) is restricted to areas where there are deeper sandy rises such as at the zone between lunettes and the surrounding sandplains. The few small clumps of *Acacia melvillei* woodland (17) are also confined to sandy sections.

Belah-Rosewood woodland is widespread across the survey area. This is an open woodland with an understorey (where present) of chenopods, grasses and shrubs such as *Myoporum* and *Senna* species. The sandplain also supports significant stands of Sandplain Mallee (3d). In contrast to the two other mallee communities, the understorey of this vegetation type is dominated by chenopod shrubs - a feature of soils with a higher clay content. This mallee type is most common in the eastern half of the mapped area, but also occurs adjacent to the Darling River floodplain in the west.

Shrublands of Black Bluebush (8) occur in the eastern portion of the survey area, particularly in the transition zones between sandplain and lacustrine or alluvial landforms. Pearl and Black Bluebush (8p) is more limited in extent in the southeast.

Table 3. Species of particular conservation significance recorded within the Pooncarie 1: 250 000 map sheet area, their conservation status, locations and source of record.

National Conservation Status codes (Briggs & Leigh 1996): **2** = maximum geographic range < 100 km; **3** = distribution of > 100 km; **K** = poorly known; **V** = vulnerable; **C** = present in conservation reserve; **a** = adequately conserved; **i** = inadequately conserved. Status in **New South Wales** (Schedules 1 and 2 of the 1995 NSW Threatened Species Conservation Act) and **Victoria** (Gullan et al. 1990): **e** = endangered, **v** = vulnerable, **Ext** = presumed extinct. Status in the **Western Division** (Pressey et al. 1990)–**Category**: **1** = species occurring only in the Western Division; **2** = species occurring only in NSW with a restricted distribution; **3** = species with a restricted distribution in the Western Division but also occurring interstate; **A** = small range and/or few records; **B** = wide range and/or many records; **X** = presumed extinct; **Priority**: Protection measures in the Western Division will **1** = solely determine; **2** = be very important in; **3** = influence a species' conservation; or **4** is desirable to conserve the genetic variation across its range.

Species	**Conservation Status**			**West'n Div'n** Categ./Prior	**Comm.**	**Sites**	**Source**
	Nat'l	**NSW**	**Vic**				
Abutilon fraseri			e		29	32	
Acacia acanthoclada		e		3B/4	-	-	Nat Herb
Acacia carnei	3VCi	v		3A/2	-	-	Nat Herb
Acacia loderi			v		4	adj. 106	
Acacia melvillei			v		4,17	59,85, adj. 3	
Amaranthus grandiflorus				3B/4			
Amaranthus macrocarpus var. *macrocarpus*			v		18	108	
Amyema linophyllum subsp. *orientale*			v		-	- -	Westbrooke & Miller('95)
Angianthus brachypappus			v		-		Rice ('86)
Atriplex angulata			v		8, 8p, 19, 22	Many	
Atriplex infrequens	2V	v		1/1	-	-	Nat Herb
Atriplex stipitata			v		4, 17, 3abd, 8	Many	
Boronia caerulescens				3B/4	-	-	Nat Herb
Bossiaea walkeri			e		3ab	Many	
Brachycome exilis				3B/4	3d	52	
Brachycome papillosa	3V	v		2/2	-	-	Nat Herb
Calandrinia disperma				3A/4	-	-	Nat Herb
Ceratogyne obionoides				3B/4	-	-	Rice ('86)
Cheilanthes lasiophylla				3B/4	29	32, 78	
Codonocarpus pyramidalis	3VCi	Ext		3A(X)/2	-	-	
Digitaria ammophila			v		30	adj.89	Rice ('86)
Eleocharis pallens			v		-	-	Rice ('86)
Eremophila sturtii			e		4, 17, 3ad	Many	
Eucalyptus porosa				3B/4	-	-	Nat Herb

Species	**Conservation Status**			**West'n Div'n Categ./Prior**	**Comm.**	**Sites**	**Source**
	Nat'l	**NSW**	**Vic**				
Euphorbia planiticola			e		8,22	31, 36, 100, 101	
Exocarpos sparteus				3B & 4A/4	3a	44	
Geijera parviflora			e		3a, 4, 29, 30	Many	
Glycine canescens			e		29	32	
Grevillea pterosperma				3B/4	3a	adj.91	
Gyrostemon australasicus				3A/3	-	-	Nat Herb
Haloragis glauca			v		2,3a	80,84	
Ixiolaena tomentosa			v		17	59	
Lepidium phlebopetalum			v		4	42	
Leptorhynchos waitzia		e	v	3B/4	-	-	Rice ('86)
Leucochrysum molle			v		13	82	
Marsdenia australis			v		4, 16, 3abd	Many	
Muehlenbeckia diclina				3B/4	-	-	Nat Herb
Olearia subspicata			v		3b	adj.97	
Opercularia turpis				3B/4	3b	adj.97	
Pachymitus cardaminoides				3B/4	29	78	
Phlegmatospermum eremaeum	3KCi		v	3A(X)/2	-	Westbrooke & Miller('95)	
Pimelea simplex subsp. *continua*				3B/4	3a	11	
Podotheca angustifolia				3B/4	-	-	Nat Herb
Ptilotus nobilis			e		-	-	Rice ('86)
Ptilotus obovatus var. *obovatus*			Ext		4, 17, 3a	33, 58, 18	
Ptilotus polystachyus var. *polystachyus*			e		2,3d	110, 39	
Radyera farragei			v		2	20	
Santalum murrayanum		e		3B/4	3a	adj.99	
Scaevola depauperata			e		3b	8	
Sclerolaena convexula			v		29,3a	32, 78, 44	
Sclerolaena lanicuspis			v		8	15, 37	
Solanum karsense	3VCi	v		1/1	-	-	
Stipa tuckeri			v		-	-	Nat Herb
Swainsona greyana			v		1	71	
Swainsona phacoides			e		1	adj.71	
Vittadinia pterochaeta			e		22	100	

Both of these communities are associated with calcareous soils, with relative dominance depending on limestone content.

The dry lake systems of Willandra Creek have had a freshwater history and have given rise to grey clay, red clay and loamy sandy duplex soils. The dry lakes of the south-east have had a saline history, and have given rise to gypseous or calcareous grey clays. The more mobile sandy soil elements have accumulated in lunettes on the eastern margins of the lake beds. All these lacustrine landforms now support shrublands. Most of the lake beds are disturbed through clearing, cropping and grazing and consequently carry mostly Disturbed Shrubland Complex (22). Bladder Saltbush (11) and Bluebush communities (8 and 8p) are also scattered among this complex. In the more saline environments, *Sclerostegia tenuis* shrubland (12) also occurs. Old Man Saltbush (19) can also be found in the more depressed areas, particularly in the alluvial transition zone in the south-east. The relict lake system is a dominant feature of the survey area stretching across from the north-east to the south-west of the map sheet. The lunettes bordering the lakes carry a Lunette Shrubland (30) dominated by the 'woody weed' *Dodonaea viscosa* subsp. *angustissima*. It is a very disturbed community suffering from high rabbit numbers and erosion. It is in the lunettes of the Willandra Lakes that were found archaeological remains of such significance that the Willandra Lakes World Heritage Region was declared.

In contrast, alluvial systems occupy much less area. The Darling River just loops into the map area in the far west and the riverine plain just overlaps with the south-eastern corner. The only forest community — Riverine Forest (1) — occurs almost exclusively along the immediate floodplain of the Darling River on heavy grey clay soils. *Eucalyptus camaldulensis,* the main species of this community, is also found sporadically in other alluvial situations, but Black Box Woodland (2) is usually dominant along other minor creeks and depressions. This woodland is also found on the higher levels of the Darling River floodplain. In intermittently flooded depressions, areas of Canegrass (13) and Lignum and Nitre Goosefoot (18) occur. These swampy communities are most commonly distributed along the alluvial areas associated with the Willandra Creek, especially in the north-east in the Gunnaramby Swamp.

The only piece of hilly country is in the north-east on Manfred Hill. This sandstone ridge gives rise to shallow sandy and stony soils. The Rocky Outcrop Woodland Complex (29) is confined to this low range and has been much modified due to grazing, particularly by goats.

Modifications induced by European land use

Across Australia, nearly 70% of all native vegetation has been removed or significantly modified since 1788 (State of the Environment Advisory Council 1996). The rate of land clearance has accelerated over time, with as much cleared during the last 50 years as in the 150 years before 1945. On a continental scale, native vegetation is still being cleared at a rate of 600 000 hectares per year, while New South Wales accounts for approximately 150 000 hectares of this figure annually (State of the Environment Advisory Council 1996).

The natural systems of western New South Wales in particular have been altered by European agricultural practices (Pickard 1994). The parlous state of the Western Division at the end of nineteenth century was acknowledged by the appointment of a Royal Commission in 1900. The combination of European land use and the introduction of the rabbit in the fragile soils of western New South Wales caused significant land degradation and led to losses of native plants and animals (Benson 1991, Pickard 1991, Lunney 1994). Pickard (1994) estimated that fencing the properties of the Western Division alone was responsible for the removal of 10^7 trees — mainly *Acacia* and *Callitris* species.

Large scale and rapid modifications occurred last century when sheep numbers were very high. From 1885 to 1897 the average number of sheep carried annually in the Western Division was 13.5 million (Lunney 1994). Gol Gol station (now part of Mungo National Park) was heavily overstocked in the 1860s and large quantities of perennial vegetation were cut for feed (Westbrooke & Miller 1995). These effects were also compounded by the spread of the rabbit and the impact of devastating drought at the end of the 1800s.

The degree of change to plant communities is a result of an interaction between the vegetation type and the timing and intensity of the disturbance. The Riverine Forests have been heavily used for timber and the understorey has been grazed. Regeneration cycles of floodplain communities such as the Riverine Forest and Black Box Woodland are disrupted by the now unnatural, regulated flow of the Darling River. The water quality of the river itself is declining due to increasing siltation from run-off of denuded and eroded areas, turbidity from European carp, inadequate flushing and salinisation (Budd et al. 1990). Other swamp communities — Lignum and Canegrass — also endure degradation through trampling by feral pigs and burning and clearing for cropping.

Clearing for cropping has by far the most damaging effect on native vegetation and is regarded by some conservationists as one of the Western Division's biggest threats (Lembit 1983). Clearing completely removes the native vegetation and prevents regeneration. Cropping activities are principally confined to the heavier soils of the dry lake beds of the Willandra Creek system. Previously cropped paddocks no longer contain Saltbush and Bluebush communities. Instead, they now support Disturbed Shrubland Complex of *Dissocarpus paradoxus*, *Nitraria billardieri* and *Sclerolaena* species.

Clearing for cropping on lighter soils is less common, but is occurring in the Mallee dunefields of the south-west of the map. As well as loss of vegetation and increased soil erosion, this activity has ramifications for groundwater recharge and increased river salt loads. When Mallee or Belah-Rosewood is cleared in this area, the groundwater recharge rate increases 100-fold (Budd et al. 1990). Because the ancient river system of the sandplain drains this extra groundwater, land salinisation is not expected as a result. However, the mobilised salt load will be deposited in the contemporary river system (Budd et al. 1990).

The significant land degradation consequences of clearing Mallee makes it an unacceptable land use (e.g. Groves & Parsons 1989, Cairnes 1989, Budd et al. 1990). However, a survey of lessees of the Western Division revealed that 34% considered clearing an improvement of mallee country (Choate 1989). The repercussions of this type of land use must be more effectively communicated to the rural community.

Similarly, there are different interpretations of the effects of grazing in the rangelands with long-term changes often not recognised by graziers. This is not surprising as some plant species live for decades (e.g. *Atriplex vesicaria*) or centuries (e.g. *Maireana sedifolia*) (Muir 1992). Also graziers are often advised that the overriding influences on vegetation are climatic and that good rainfall inevitably leads to regeneration of vegetation (Stanley 1983). This may only be the case in the absence of heavy grazing — management frequently dominates over seasonal variations (Pickard 1991). It is generally acknowledged, however, that continual grazing replaces palatable perennial native species with less desirable, often exotic, annuals (Stanley 1983). Introduced plants are an acute and insufficiently appreciated ecological problem. Approximately 20% of vascular plant species in New South Wales are naturalised exotics (Benson 1991). Even though the survey reported here was conducted at a time of drought, still 12% of the species recorded were exotic.

The lack of recruitment of many woody species has long been recognised as a management problem in arid and semi-arid regions (Harrington et al. 1984). *Heterodendrum oleifolium* — a major component of Belah-Rosewood Woodlands in the study area — has rarely been observed to establish from seed and relies on root suckering for regeneration (Wisniewski & Parsons 1986). It will not regenerate adequately when grazed by stock, but still needs episodic disturbance (such as fire) to stimulate suckering (Wisniewski & Parsons 1986).

The future of other woody species in grazing areas are equally tenuous. *Acacia melvillei*, for example, suffers serious regeneration problems. The few sites of this shrubland community in the survey area contained no understorey (no new recruits of any woody species) due to grazing pressure by sheep and rabbits. Batty and Parsons (1992) reported an almost total failure of *Acacia melvillei* regeneration in pastoral areas studied nearby at Balranald.

Some unpalatable woody species are regenerating, however, and the proliferation of these 'woody weeds' is considered a major land degradation problem. These shrubs are mainly species of *Dodonaea*, *Eremophila* and *Senna* (Muir 1992). Their increase is attributed to changes in the fire regime, the grazing out of competitive pasture species and the disturbance of the soil surface by stock and erosion (Green 1988). Their germination is episodic and the resultant groves lead to a reduction in pasture productivity and general loss of species diversity. The bare ground between individual bushes is then exposed to soil erosion by flow and runoff. In dense stands, however, while the soil surface may be bare, the shrubs can protect the surface from wind erosion (Green 1988).

The presence of other grazers in the system has an accumulative grazing effect on the vegetation. Rabbit densities are highest in sandy country — particularly in sandy rises and lunettes. Goats are mainly found in mallee areas and on the rocky Manfred Hill. The number of feral grazers is significant. A conservative estimate of rabbit grazing load in the Willandra Lakes World Heritage area was 3–4 times that of domestic stock (Fatchen & Fatchen 1989). The increase in the number of watering points throughout the area has probably also increased the number of native grazers (Red and Western Grey Kangaroos).

Fire is an infrequent yet pivotal event in this landscape. The last extensive wildfire was in the summer of 1974–75 following significant fuel build-up over a number of wetter seasons. There was abundant speargrass (*Stipa* spp.) across open areas linking highly-flammable Mallee communities (Noble 1989) thus allowing for large swathes of country to be burnt. Eventually 340 000 ha was burnt out in the district (Lans et al. 1988). Prior to these big fires, only minor localised fires were known on 'Tapio' and 'Turlee' in 1931 and on 'Garnpung' and 'Wonga' in 1960 (Lans et al. 1988).

The use of fire by Aboriginal people for manipulation of their environment was observed by early European explorers. However, the fire regime — how often and in what seasons they occurred — is a matter for conjecture. In dunefield mallee with an understorey dominated by *Triodia scariosa* subsp *scariosa*, Noble (1989) estimates that it is unlikely that the fire frequency could exceed more than one fire every 15–20 years as it takes this amount of time for sufficient fuel to accumulate. The season of burn is the most critical factor in shaping the species composition of mallee in this area (Noble 1989), so care must be taken in applying it as a management tool.

Conservation of the vegetation

Despite the great changes that have been wrought on the landscape by European agriculture, the future of native vegetation in the Pooncarie district does look promising as there are now significant interests in maintaining the area's natural values. The Pooncarie map contains 92% of the Willandra Lakes World Heritage region. The management strategy for this important area must protect its world heritage values. This should translate into conservative use of the dry lake beds and their fringing lunettes. Mungo National Park attracts large numbers of tourists to the area, which creates public scrutiny of its management. Tourist operators also have an interest in the maintenance of the area's natural values.

The map area contains large expanses of uncleared Mallee country which is largely intact. The major management challenge for this area is to decrease the grazing pressure. This is most easily achieved by reducing the number of watering points.

With the recent introduction of the Rabbit Calicivirus Disease, the future for rabbits is bleak. No live rabbits were observed during the final field traverses in 1996. A crash in the rabbit population may allow for regeneration of many plant species in the sandplains and sandy rises.

In western New South Wales there are now Landcare groups, Total Catchment Management Groups, Save the Bush programmes, salinity action groups and revegetation projects run by organisations such as Greening Australia (Denny 1994). The Royal Botanic Gardens has produced extension material related to this mapping programme in an attempt to encourage an appreciation of native vegetation (Driver & Porteners 1993, Porteners & Ashby 1996). As much of the impetus behind these programmes is community-based, there is a real chance that the landcare philosophy will translate into land use practices.

Perhaps the most encouraging feature of this region is the resilience of the vegetation itself. If the plants are freed from the stresses of inappropriate grazing, inappropriate fire and clearing and cropping, many of the communities have the capacity to return with some vigour when climatic conditions are favourable. It is not known, however, how far a system can be pushed before it loses its inherent recuperative abilities. The precautionary principle should be applied to the land management in this area where the systems are still largely intact.

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Appendix 1. Attributes of sites sampled in the Pooncarie 1: 250 000 map sheet area.

Key: Site = site number; * = site in excellent condition; ^{B} = site in good condition; Map = 1:100 000 topographic map sheet name; East/North = full Australian Map Grid (AMG) reference (Zone 54); Soil (classified from field observations): Lt = light; Dk = dark; R = red; B = brown; G = grey; W = white; S = sand/sandy; L = loam/loamy; C = clay/clayey; c = cracking; ss = sandstone conglomerate; ca = calcareous; Alt. = altitude (m); Veg. = vegetation community classification; TSP = total number of species; NSP = number of native species; ESP (%) = number of exotic species (percentage of total).

Site	Map	Location	East	North	Soil	Landform	Alt.	Veg.	TSP	NSP	ESP(%)
001	Turlee	Ryah Box Flat	708600	6238500	RLS	dunecrest	80	3b	21	21	0 (0)
002	Turlee	Hatfield Rd E of Ryah Box Flat	726400	6242700	BLC	depression	40	11	23	22	1 (4)
003	Turlee	Hatfield Rd E of Ryah Box Flat	722800	6242100	RBL	sandplain	80	4	18	18	0 (0)
004^B	Turlee	Northern Lake Mungo	687500	6272800	LtBCL	dry lake	60	8	16	16	0 (0)
005	Turlee	S of 'Garnpung'	695200	6289900	RLS	lunette	80	8	17	14	3 (6)
006	Mulurulu	Garnpung Lake	707100	6292300	GLC	dry lake	60	22	16	15	1 (6)
007^B	Mulurulu	'Gol Gol'	716500	6292700	RLS	low rise	90	16	18	14	4 (22)
008^B	Turlee	Balranald Rd E of Garnpung Lake	718900	6285000	RLS	dunecrest	90	3b	19	19	0 (0)
009^B	Turlee	S of 'Boree Plains'	722600	6260500	RLS	dunecrest	115	3b	18	17	1 (6)
010^B	Turlee	SE of 'Boree Plains'	725600	6258200	RSL	sandplain	100	4	16	16	0 (0)
011^B	Mulurulu	NE of 'Gol Gol' on Ivanhoe Rd	720600	6297000	RLS	duneslope	80	3a	16	16	0 (0)
012	Mulurulu	Ivanhoe Rd E of Hatfield Rd	743400	6307200	RBSL	sandplain	70	4	16	16	0 (0)
013*	Manfred	'Binda'- Hatfield Rd	742700	6295300	RLS	dunecrest	80	3a	14	14	0 (0)
014	Hatfield	E of 'Round Plain'	752300	6271700	RSL	sandplain	80	4	12	11	1 (8)
015	Hatfield	Ivanhoe Rd N of Hatfield	765700	6265900	BCL	scald. plain	70	8	17	15	2 (12)
016	Hatfield	Balranald Rd S of Hatfield	748700	6243300	BcC	dry lake	60	11	9	8	1 (11)
017	Arumpo	Durthong Tank	773400	6273200	BLC	dry lake	60	8	22	15	7 (32)
018	Arumpo	Pooncarie Rd W of Lake Mungo	662000	6270800	RS	duneslope	100	3a	19	19	0 (0)
019^B	Arumpo	SE of Wild Dog Tank	646500	6277900	RS	duneslope	60	3a	20	20	0 (0)

Site	Map	Location	East	North	Soil	Landform	Alt.	Veg.	TSP	NSP	ESP(%)
020	Pooncarie	Darling River S of Pooncarie	644600	6301100	GC	floodplain	45	2	18	16	2 (11)
021	Pooncarie	Darling River S of Pooncarie	645900	6301700	GBcC	riverbank	20	1	14	12	2 (14)
022	Pooncarie	Ivanhoe Rd W of Pooncarie Loop	679000	6313500	RLS	dunecrest	80	3a	12	12	0 (0)
023	Mulurulu	Pooncarie Rd W of Garnpung Lk	689700	6315800	RSL	sandplain	80	4	13	13	0 (0)
024	Mulurulu	S of 'Bulgamurra'	689500	6326700	RBSL	sandplain	60	4	13	13	0 (0)
025	Mulurulu	N of 'Wilkurra'	694800	6339500	RS	dunecrest	65	3a	19	19	0 (0)
026	Pooncarie	SSW of Mitfords Corner	653900	6340000	RBSL	sandplain	60	3d	11	11	0 (0)
027	Pooncarie	NE of Pambra Tank	645000	6332200	RBSL	sandplain	60	3d	10	10	0 (0)
028	Pooncarie	Pambra Tank swamp	644700	6330900	GBcC	depression	50	13	4	4	0 (0)
029	Pooncarie	Darling River N of Pooncarie	645500	6307700	GcC	swamp	40	18	8	6	2 (25)
030	Pooncarie	Menindee Rd N of Pooncarie	645400	6308200	RBLC	floodplain	50	2	20	18	2 (10)
031	Manfred	Willandra Ck on Darnick Rd	744200	6314300	LtBcC	dry lake	70	22	22	14	8 (36)
032	Manfred	Manfred Mountain, highest point	747300	6323000	BLss	ridge crest	160	29	29	27	2 (7)
033	Manfred	NW of 'Melton Grove'	747300	6324600	RBSL	sandplain	80	4	18	18	0 (0)
034	Mulurulu	Darnick Rd SW of 'C Lake'	726100	6333600	RLS	sandplain	70	3d	15	14	1 (7)
035	Mulurulu	Darnick Rd NE of 'Pan Ban'	704700	6316300	GBcC	dry lake	70	18	11	9	2 (18)
036	Mulurulu	Garnpung Lake N of 'Garnpung'	696600	6305600	GBcC	dry lake	70	22	13	11	2 (15)
037^{B}	Manfred	Ivanhoe Rd SE of 'Manfred'	759700	6309500	GBC	scald. plain	70	8	25	23	2 (8)
038	Manfred	Ivanhoe Rd S of 'Clare'	767900	6291500	GBLC	alluv. plain	50	19	20	14	6 (30)
039	Manfred	Ivanhoe Rd S of 'Clare'	770900	6297600	RLS	sandplain	70	3d	18	18	0 (0)
040^{B}	Manfred	Gunnaramby Swamp, Lake Tank	774700	6324300	GBC	floodplain	60	2	17	17	0 (0)
041^{B}	Arumpo	Mildura Rd SE of Mungo Lodge	675400	6255200	BC	depression	60	11	15	15	0 (0)
042	Arumpo	Mildura Rd W of 'Bellnar'	652300	6239700	RBSL	sandplain	90	4	24	23	1 (4)

Site	Map	Location	East	North	Soil	Landform	Alt.	Veg.	TSP	NSP	ESP(%)
043^{B}	Arumpo	Mildura Rd W of 'Bellnar'	647400	6239500	RS	dunecrest	100	3b	24	24	0 (0)
044^{B}	Arumpo	Petro Mail Rd W of 'Murragi'	641000	6249000	RS	dunecrest	100	3a	17	17	0 (0)
045	Turlee	Chibnalwood Lake	688800	6252100	LtBcaCL	lunette	60	8	21	18	3 (14)
046	Turlee	Lake Mungo Rd NW of 'Turlee'	685600	6245900	LtBcaCL	scald. plain	60	4	13	13	0 (0)
047	Turlee	Garnpung Rd within Mungo NP	687000	6268500	RS	sandplain	80	3d	13	11	2 (15)
048^{B}	Turlee	Lake Mungo within Mungo NP	692500	6264000	LtBCL	dry lake	60	11	9	8	1 (11)
049	Mulurulu	E edge of Garnpung Lake	714500	6292500	LtRBL	lunette	90	30	31	23	8 (26)
050	Mulurulu	Ivanhoe Rd SE of 'Mandleman'	730000	6303000	RS	low rise	80	16	19	10	9 (47)
051	Hatfield	'Magenta' Rd on 'Binda'	740000	6286000	RBS	sandplain	100	4	16	16	0 (0)
052	Hatfield	Near Whitties Tank	736000	6267000	RBLS	sandplain	80	3d	23	22	1 (4)
053	Hatfield	Balranald Rd S of 'Magenta'	737000	6247000	BCL	plain	70	8	10	9	1 (10)
054^{B}	Arumpo	Pooncarie Rd SE Big 16 Mile Tank	656000	6272500	RS	duneslope	100	3a	17	17	0 (0)
055^{B}	Arumpo	Mildura Rd E of Petro Mail Rd	585000	6240500	RS	duneslope	80	3b	29	28	1 (3)
056	Arumpo	Euston Rd SE of Lake Mungo Rd	672500	6241500	RBL	scald. plain	80	8	9	8	1 (11)
057	Arumpo	Hatfield Rd E of Mildura Rd	680000	6243000	RS	duneslope	80	3d	15	15	0 (0)
058	Mulurulu	Lake Mulurulu S of 'C Lake'	722500	6328000	WcaS	lunette	90	30	9	5	4 (44)
059	Mulurulu	Ivanhoe Rd SW of 'C Lake'	718000	6329500	RBSL	sandplain	80	17	19	18	1 (5)
060	Mulurulu	Hughies Bore from Ivanhoe Rd	713500	6328000	RSL	sandplain	90	4	11	11	0 (0)
061	Mulurulu	NW of 'Yarraman'	706000	6321000	RS	dunecrest	80	3a	11	11	0 (0)
062	Arumpo	Mildura Rd SW of Lake Mungo	675000	6252500	GBC	scald. plain	60	8	15	13	2 (13)
063^{B}	Turlee	Balranald Rd E of 'Turlee'	697500	6240500	RLS	duneslope	90	3b	29	29	0 (0)
064^{B}	Turlee	Mungo NP tourist drive	701500	6269000	LtRBS	dunecrest	80	3a	24	24	0 (0)
065	Hatfield	Turlee Rd SE of 'Langley Dale'	738000	6238000	BcC	depression	70	19	20	17	3 (15)

Site	Map	Location	East	North	Soil	Landform	Alt.	Veg.	TSP	NSP	ESP(%)
066	Hatfield	'Freemount' SE of Hatfield	767000	6239000	GBCL	scald. plain	75	8	7	6	1 (14)
067	Hatfield	'Freemount' SE of homestead	763500	6239500	GBL	alluv. plain	70	11	7	6	1 (14)
068	Hatfield	Ivanhoe Rd N of Hatfield	757000	6257500	GBL	depression	70	19	9	6	3 (33)
069	Hatfield	Ivanhoe Rd N of Hatfield	756000	6254000	RBL	low rise	60	8p	14	12	2 (14)
070	Pooncarie	NNW of Pooncarie	643000	6311500	LtRBSL	sandplain	60	3d	14	12	2 (14)
071	Pooncarie	Darling River S of Pooncarie	646000	6304000	GcC	riverbank	40	1	30	20	10 (33)
072	Arumpo	Wentworth Rd near 'Peaka'	640000	6287000	BLC	floodplain	40	2	17	12	5 (29)
073	Arumpo	Wentworth Rd SW of Pooncarie	646000	6290000	RLS	sandplain	55	3d	17	13	4 (23)
074	Pooncarie	Darnick Rd NE of Pooncarie Rd	658000	6347000	RBLS	sandplain	60	4	9	9	0 (0)
075	Pooncarie	Garnpung Rd NE of Pooncarie	664000	6307000	RLS	dunecrest	75	3a	21	21	0 (0)
076[B]	Pooncarie	S of Ivanhoe Rd E of Pooncarie	674000	6308500	RS	dunecrest	80	3a	11	11	0 (0)
077	Pooncarie	N along Pooncarie Loop Rd	685000	6318000	RS	low dune	70	3b	16	16	0 (0)
078	Manfred	NE end of Manfred Range	750500	6325000	DkBL	ridge crest	140	29	32	24	8 (25)
079	Manfred	SE footslopes of Manfred Range	751000	6324500	RSLss	ridge slope	80	4	17	16	1 (6)
080[B]	Manfred	Gunnaramby Swamp creek	777000	6328500	GcC	creek bed	70	2	41	34	7 (17)
081	Manfred	'Peneena' Rd W of Gunnaramby	770000	6331000	RBL	scald. plain	80	8	22	18	4 (18)
082	Manfred	Ivanhoe Rd N of 'Melton Grove'	775000	6317000	GBcC	depression	70	13	24	20	4 (17)
083	Manfred	Hatfield Rd S of 'Melton Grove'	773000	6304000	RLS	low rise	80	16	16	11	5 (31)
084	Manfred	Pooncarie Rd W 'Melton Grove'	737500	6303500	RS	low dune	75	3a	14	13	1 (7)
085	Manfred	Opposite 'Dockerty'	739000	6321500	RLS	sandplain	80	17	11	9	2 (18)
086	Arumpo	Pooncarie-Wentworth Rd	642500	6287000	RS	low rise	60	16	9	6	3 (33)
087	Pooncarie	Firebreak NE of Swamp Tank	677000	6327000	RBSL	sandplain	80	4	9	9	0 (0)
088[B]	Pooncarie	Firebreak N from Pooncarie Rd	678500	6337000	RS	dunecrest	80	3b	16	16	0 (0)

Site	Map	Location	East	North	Soil	Landform	Alt.	Veg.	TSP	NSP	ESP(%)
089	Mulurulu	Garnpung Lake SE of 'Balmoral'	699000	6307000	WcaS	lunette	90	30	11	7	4 (36)
090	Arumpo	Lake Mungo Rd SE of 'Top Hut'	680000	6272000	BCL	scald. plain	80	8	6	6	0 (0)
091*	Arumpo	Fenceline SW of 'Top Hut'	669500	6263000	RS	dunecrest	85	3a	16	16	0 (0)
092	Arumpo	Mildura Rd S of 'Top Hut'	677500	6267000	RS	low rise	70	16	10	7	3 (30)
093	Arumpo	N of 'Old Arumpo'	675500	6259500	LtBLC	saline plain	60	12	9	8	1 (11)
094^{B}	Arumpo	Pipeline track NW of 'Murragai'	646000	6259000	RS	duneslope	80	3a	14	14	0 (0)
095	Turlee	Lake Leaghur	691500	6282500	GcC	dry lake	60	22	9	9	0 (0)
096	Turlee	N edge of Lake Mungo	691000	6274000	GBCL	low lunette	70	8p	8	8	0 (0)
097^{B}	Arumpo	Pipeline road SE of 'Turlee'	695000	6236500	RS	dunecrest	80	3b	24	24	0 (0)
098	Manfred	Darnick Rd NW 'Melton Grove'	737500	6331000	RLS	sandplain	70	3d	12	11	1 (8)
099	Mulurulu	Garnpung Rd SW 'Mandleman'	727000	6303000	RLS	dunecrest	85	3a	8	8	0 (0)
100	Manfred	Willandra Ck E 'Melton Grove'	749500	6308500	GBcC	dry lake	70	22	11	9	2 (18)
101^{B}	Manfred	E of 'Clare'on road to Cobb Hwy	777000	6299000	RBCL	scald. plain	75	8	22	20	2 (9)
102	Hatfield	Hatfield Rd S of 'Clare' Rd	766000	6271500	GcC	depression	70	19	12	11	1 (8)
103	Hatfield	Hatfield Rd E of 'Magenta'	742500	6249000	RBSL	scald. plain	70	8p	11	10	1 (9)
104	Hatfield	Balranald Rd S of 'Magenta'	737500	6246500	LtBcC	saline plain	60	12	8	8	0 (0)
105	Hatfield	The Vale Rd SE 'Melton Grove'	744000	6282000	RBS	sandplain	80	3d	18	18	0 (0)
106^{B}	Manfred	'Girrawheen' Rd	746500	6331500	RSL	sandplain	70	4	20	20	0 (0)
107	Manfred	'Pentola' E of 'Girrawheen'	753500	6343500	GBcC	swamp	60	13	3	3	0 (0)
108	Manfred	Bourkes Tank Swamp SE	756500	6336000	GBcC	swamp	70	18	12	10	2 (17)
109	Manfred	N of 'Peneena'	765000	6375000	GBLC	alluv. plain	80	22	14	12	2 (14)
110	Manfred	Willandra Ana Branch	768500	6338000	LtBSC	creek bed	80	2	25	24	1 (4)

Appendix 2. Species list for communities identified on the Pooncarie 1: 250 000 map sheet area.

Key

Figures show % occurrence of species in sites per community and overall; X = species occurring outside 50×20 metre survey quadrat; F = open forest, W = woodland, M = mallee, S = shrubland, G = grassland, A = all communities; 1 = Riverine Forest, 2 = Black Box Woodland, 3a = Irregular Dune Mallee, 3b = Linear Dune Mallee, 3d = Sandplain Mallee, 4 = Belah-Rosewood, 8 = Black Bluebush, 8p = Pearl Bluebush, 11 = Bladder Saltbush, 12 = *Sclerostegia tenuis*, 13 = canegrass, 16 = *Callitris* Mixed Woodland, 17 = *Acacia melvillei* Woodland, 18 = Lignum and Nitre Goosefoot, 19 = Old Man Saltbush, 22 = Disturbed Shrubland Complex, 29 = Rocky Outcrop Woodland Complex, 30 = Lunette Shrubland; * = exotic species; ◆ = extension of known range in NSW (specimen held at National Herbarium of New South Wales); ✸ = species nationally listed as Rare or Threatened Australian Plants (ROTAP) (Briggs & Leigh 1995); ★ = species listed on Schedules 1 and 2 of the 1995 NSW Threatened Species Conservation Act; ✣ = plant taxon with restricted distribution in the Western Division of NSW (Pressey et al. 1990); ❖ = rare or threatened taxon in Victoria (Gullan 1990); names in square brackets [] are recent synonyms.

Other records:

^{BR} = Rice, B. (1986) Aspects of the vegetation of the Willandra World Heritage Region (Final report to the NSW Department of Environment and Planning on investigations under the National Estates Program)

^{MW} = Westbrooke, M.E. and J.D. Miller (1995) Vegetation of Mungo National Park, western New South Wales. *Cunninghamia (4)1:* 63–80

^{NH} = National Herbarium of New South Wales record.

Pooncarie Species List

Family/Species	F	W	W	W	W	W	M	M	M	S	S	S	S	S	S	S	S	G	A
	1	2	4	16	17	29	3a	3b	3d	8	8p	11	12	18	19	22	30	13	All
Aizoaceae																			
Disphyma crassifolium subsp. *clavellatum*	-	-	-	-	-	-	-	-	-	-	-	80	100	-	-	-	-	-	6
**Mesembryanthemum crystallinum* ^{MW}																			
**Psilocaulon tenue* ^{MW}																			
Tetragonia tetragonioides	-	-	-	20	-	50	-	-	-	-	-	-	-	-	-	-	-	33	3
Amaranthaceae																			
Alternanthera denticulata	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	1
Alternanthera nodiflora	50	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2

Family/Species	F	W	W	W	W	W	M	M	M	S	S	S	S	S	S	S	S	G	A
	1	2	4	16	17	29	3a	3b	3d	8	8p	11	12	18	19	22	30	13	All
❖*Amaranthus grandiflorus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	1
◆❖*Amaranthus macrocarpus* var. *macrocarpus*	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	1
Ptilotus atriplicifolius var. *atriplicifolius*	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Ptilotus exaltatus var. *exaltatus*	-	-	-	-	-	50	25	44	18	-	-	-	-	-	-	-	-	-	10
❖*Ptilotus nobilis* BR																			
❖*Ptilotus obovatus* var. *obovatus*	-	-	7	-	50	-	6	-	-	-	-	-	-	-	-	-	-	-	3
❖*Ptilotus polystachyus* var. *polystachyus*	-	17	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	2
Ptilotus seminudus NH																			
Ptilotus spathulatus MW																			
Amaryllidaceae																			
Crinum flaccidum	-	17	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Anthericaceae																			
Corynotheca licrota BR																			
Thysanotus baueri MW																			
Apiaceae																			
Daucus glochidiatus NH																			
Trachymene cyanopetala NH																			
Apocynaceae																			
❖*Parsonsia eucalyptophylla*	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asclepiadaceae																			
❖*Marsdenia australis*	-	-	27	20	-	-	6	11	27	-	-	-	-	-	-	-	-	-	9

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
Asparagaceae																			
**Myrsiphyllum asparagoides* MW																			
Asphodeliaceae																			
**Asphodelus fistulosus*	-	-	4	40	X	50	-	11	18	X	-	-	-	-	-	-	100	-	10
Bulbine bulbosa	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	17	-	-	2
Bulbine semibarbata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	33	1
Aspleniaceae																			
Pleurosorus rutifolius	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Asteraceae																			
Actinobole uliginosum	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
❖*Angianthus brachypappus* BR																			
**Arctotheca calendula* MW																			
Brachycome ciliaris var. *ciliaris*	-	-	-	-	-	-	6	-	-	8	-	-	-	-	-	-	-	-	2
✣❖*Brachycome exilis*	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	1
Brachycome heterodonta var. *heterodonta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	1
Brachycome leptocarpa BR																			
Brachycome lineariloba MW																			
Brachycome multifida var. *multifida*	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	1
✱★❖*Brachycome papillosa* NH																			
Brachycome perpusilla var. *tenella* MW																			
Bracteantha bracteata BR																			

Family/Species	**F 1**	**W 2**	**W 4**	**W 16**	**W 17**	**W 29**	**M 3a**	**M 3b**	**M 3d**	**S 8**	**S 8p**	**S 11**	**S 12**	**S 18**	**S 19**	**S 22**	**S 30**	**G 13**	**A All**
Calotis cuneifolia	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	1
Calotis cymbacantha ^{BR}																			
Calotis erinacea	-	-	-	-	-	-	31	X	9	-	-	-	-	-	-	-	-	-	6
Calotis hispidula	-	-	-	-	-	50	-	-	9	-	-	-	-	-	-	-	33	-	3
Calotis plumulifera ^{BR}																			
Calotis scabiosifolia ^{BR}																			
**Centaurea melitensis*	-	-	-	-	-	-	-	-	-	8	-	-	-	-	25	-	-	-	2
Centipeda cunninghamii	-	17	-	-	-	-	-	-	-	15	-	20	-	33	25	-	-	-	6
Centipeda minima ^{BR}																			
✤*Ceratogyne obionoides* ^{BR}																			
Chrysocephalum apiculatum	-	-	-	-	-	-	6	11	-	-	-	-	-	-	-	-	-	-	2
Chthonocephalus pseudevax ^{MW}																			
**Cirsium vulgare*	100	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	3
**Cotula bipinnata* ^{BR}																			
Craspedia haplorrhiza ^{BR}																			
Eclipta platyglossa	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elachanthus pusillus ^{BR}																			
Gnephosis arachnoidea ^{BR}																			
Gnephosis tenuissima	-	17	-	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
**Hedypnois rhagadioloides* subsp. *cretica* ^{BR}																			
Hyalosperma semisterile	-	-	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-

Family/Species	F	W	W	W	W	W	M	M	M	S	S	S	S	S	S	S	S	G	A
	1	2	4	16	17	29	3a	3b	3d	8	8p	11	12	18	19	22	30	13	All
**Hypochaeris glabra*	-	17	-	20	-	-	-	-	-	-	-	-	-	-	-	-	33	-	3
**Hypochaeris radicata*	50	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	2
Isoetopsis graminifolia ^{MW}																			
Ixiolaena leptolepis	-	-	-	-	-	-	-	-	-	X	33	-	-	-	-	-	-	-	1
❖*Ixiolaena tomentosa*	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	1
◆❖*Leptorhynchos panaetioides*	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	2
★✣❖*Leptorhynchos waitzia* ^{BR}																			
❖*Leucochrysum molle*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	1
Microseris lanceolata ^{BR}																			
Millotia greevesii var. *greevesii* ^{NH}																			
Millotia macrocarpa ^{NH}																			
Millotia perpusilla ^{MW}																			
Minuria cunninghamii	-	-	-	-	-	-	-	-	-	31	33	40	X	-	-	17	-	33	8
❖*Minuria denticulata*	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	1
❖*Minuria integerrima*	-	-	-	-	-	-	-	-	-	8	-	-	-	-	25	-	-	-	2
Minuria leptophylla	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Myriocephalus stuartii	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67	-	3
Olearia lepidophylla	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1
Olearia magniflora	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	1
Olearia muelleri	-	-	13	-	-	-	-	11	9	-	-	-	-	-	-	-	-	-	4
❖*Olearia passerinoides* subsp. *passerinoides*	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
Olearia pimeleoides	-	-	13	-	-	-	-	11	9	-	-	-	-	-	-	-	-	-	4
❖*Olearia subspicata*	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-
**Onopordum acaulon* ^{MW}																			
❖*Podolepis canescens* ^{BR}																			
Podolepis capillaris	-	-	-	-	-	-	50	33	-	-	-	-	-	-	-	-	-	-	10
❖*Podotheca angustifolia* ^{NH}																			
Pogonolepis stricta ^{BR}																			
Pseudognaphalium luteoalbum	-	17	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	2
Pycnosorus chrysanthus ^{BR}																			
Pycnosorus pleiocephalus	-	-	X	-	-	-	-	-	X	X	-	-	-	-	-	X	-	-	-
Rhodanthe corymbiflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-
Rhodanthe floribunda	-	X	X	-	-	-	-	-	X	8	-	-	-	-	-	X	X	-	1
Rhodanthe moschata	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
❖*Rhodanthe polygalifolia* ^{BR}																			
Rhodanthe pygmaea	-	-	X	-	-	-	-	-	X	-	33	-	-	-	-	-	-	-	1
Rhodanthe stuartiana ^{NH}																			
Rhodanthe tietkensii	-	-	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
Rhodanthe uniflora ^{BR}																			
Senecio cunninghamii ^{BR}																			
Senecio glossanthus ^{NH}																			
Senecio gregorii ^{BR}																			

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
Senecio lautus subsp. *dissectifolius*	-	-	-	-	-	-	6	-	-	X	-	-	-	-	-	-	-	-	1
Senecio runcinifolius	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	1
Sigesbeckia australiensis	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Sigesbeckia orientalis subsp. *orientalis*	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	1
**Sonchus asper* subsp. *glaucescens*	-	17	-	-	-	-	-	-	-	15	-	-	-	-	-	17	-	-	4
**Sonchus oleraceus*	50	-	-	20	-	-	-	-	9	-	-	-	-	-	25	-	33	-	5
Vittadinia cervicularis var. *cervicularis*	-	-	7	-	-	-	6	22	18	-	-	-	-	-	-	-	-	-	6
Vittadinia cuneata var. *cuneata*	-	-	-	-	-	-	6	33	-	-	-	-	-	-	-	-	-	-	4
Vittadinia cuneata var. *hirsuta* NH																			
Vittadinia cuneata var. *morrisii*	-	-	7	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	2
Vittadinia dissecta var. *hirta*	-	-	-	-	-	-	19	11	9	-	-	-	-	-	-	-	-	-	5
Vittadinia gracilis	-	17	7	-	50	100	-	-	9	23	-	-	-	-	-	-	33	-	9
❖*Vittadinia pterochaeta*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	1
Waitzia acuminata NH																			
**Xanthium spinosum*	-	17	-	-	-	-	-	-	-	8	-	-	-	X	50	-	-	-	4
Azollaceae																			
Azolla filiculoides var. *rubra* BR																			
Boraginaceae																			
**Amsinckia intermedia*	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Cynoglossum australe	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	1
**Echium plantagineum*	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	33	-	2

Family/Species	**F** **1**	**W** **2**	**W** **4**	**W** **16**	**W** **17**	**W** **29**	**M** **3a**	**M** **3b**	**M** **3d**	**S** **8**	**S** **8p**	**S** **11**	**S** **12**	**S** **18**	**S** **19**	**S** **22**	**S** **30**	**G** **13**	**A** **All**
Halgania cyanea	-	-	-	-	-	-	44	44	-	-	-	-	-	-	-	-	-	-	10
**Heliotropium europaeum*	100	-	-	40	-	-	-	-	-	15	-	-	-	-	50	-	-	-	7
**Heliotropium supinum*	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	1
**Neatostema apulum* ^{NH}																			
Omphalolappula concava ^{NH}																			
Plagiobothrys plurisepaleus ^{NH}																			
Brassicaceae																			
**Alyssum linifolium* ^{NH}																			
**Arabidella nasturtium* ^{NH}																			
**Brassica tournefortii*	50	17	-	40	-	-	-	11	18	8	-	-	-	-	-	-	67	-	9
**Capsella bursa-pastoris* ^{NH}																			
**Carrichtera annua*	-	17	-	-	-	-	-	-	-	15	-	-	-	-	-	17	-	-	4
Geococcus pusillus ^{NH}																			
Harmsiodoxa blennodioides ^{NH}																			
Harmsiodoxa brevipes ^{NH}																			
Lepidium fasciculatum ^{NH}																			
Lepidium leptopetalum ^{NH}																			
Lepidium papillosum ^{NH}																			
❖*Lepidium phlebopetalum*	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Lepidium pseudohyssopifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	1
❖*Pachymitus cardaminoides*	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Phlegmatospermum cochlearinum ^{NH}																			

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
✱✣✣*Phlegmatospermum eremaeum* $^{\mathrm{NH}}$																			
Sisymbrium erysimoides	50	33	7	X	-	X	-	-	-	-	-	-	-	33	25	17	-	-	6
Sisymbrium irio	-	17	-	20	-	50	6	-	-	-	-	-	-	-	-	-	-	33	5
**Sisymbrium orientale* $^{\mathrm{NH}}$																			
Stenopetalum lineare $^{\mathrm{NH}}$																			
Stenopetalum sphaerocarpum $^{\mathrm{NH}}$																			
Campanulaceae																			
Wahlenbergia communis	-	-	7	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	1
Wahlenbergia gracilenta	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capparaceae																			
Apophyllum anomalum	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Caryophyllaceae																			
**Herniaria hirsuta* $^{\mathrm{NH}}$																			
Scleranthus miniscculus	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Scleranthus pungens	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
**Silene apetala*	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
**Spergularia diandra* $^{\mathrm{NH}}$																			
**Spergularia rubra*	-	17	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	2
**Stellaria media* $^{\mathrm{NH}}$																			
Casuarinaceae																			
Casuarina pauper	-	-	100	20	-	X	-	-	-	-	-	-	-	-	-	-	-	-	15

Family/Species	**F** **1**	**W** **2**	**W** **4**	**W** **16**	**W** **17**	**W** **29**	**M** **3a**	**M** **3b**	**M** **3d**	**S** **8**	**S** **8p**	**S** **11**	**S** **12**	**S** **18**	**S** **19**	**S** **22**	**S** **30**	**G** **13**	**A** **All**
Chenopodiaceae																			
Atriplex acutibractea subsp. *acutibractea*	-	-	13	-	-	-	6	-	9	-	-	-	-	-	25	-	-	33	6
❖*Atriplex angulata*	-	-	-	-	-	-	-	-	-	31	33	-	-	-	25	X	-	-	6
Atriplex conduplicata $^{\mathrm{NH}}$																			
Atriplex eardleyae	-	50	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Atriplex holocarpa	-	17	-	-	-	-	-	-	-	8	-	-	-	-	-	50	-	33	6
✱★❖*Atriplex infrequens* $^{\mathrm{NH}}$																			
Atriplex intermedia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	1
Atriplex leptocarpa	100	17	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	4
Atriplex limbata	-	17	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Atriplex lindleyi	-	33	7	-	-	-	-	-	-	62	33	20	50	-	75	67	-	33	20
Atriplex nummularia	-	-	-	-	-	-	-	-	-	-	-	-	X	-	100	-	-	-	4
Atriplex pseudocampanulata	-	33	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	33	5
Atriplex pumilio $^{\mathrm{NH}}$																			
Atriplex semibaccata	-	67	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	4
Atriplex spongiosa $^{\mathrm{NH}}$																			
❖*Atriplex stipitata*	-	-	53	-	50	-	19	33	55	23	-	-	-	-	-	-	-	-	22
Atriplex suberecta	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Atriplex velutinella $^{\mathrm{NH}}$																			
❖*Atriplex vesicaria*	-	-	-	-	-	-	-	-	-	23	-	100	50	-	25	33	-	-	11
**Chenopodium album* $^{\mathrm{NH}}$																			

Family/Species	**F** **1**	**W** **2**	**W** **4**	**W** **16**	**W** **17**	**W** **29**	**M** **3a**	**M** **3b**	**M** **3d**	**S** **8**	**S** **8p**	**S** **11**	**S** **12**	**S** **18**	**S** **19**	**S** **22**	**S** **30**	**G** **13**	**A** **All**
Chenopodium cristatum	-	33	-	60	-	-	-	-	-	-	-	-	-	-	-	-	33	-	6
Chenopodium curvispicatum	-	-	33	-	-	-	-	22	9	-	33	-	-	-	25	-	-	-	9
Chenopodium desertorum subsp. *anidiophyllum* ^{BR}																			
Chenopodium desertorum subsp. *desertorum*	-	-	27	-	-	-	38	56	46	-	-	-	-	-	-	-	-	-	18
Chenopodium desertorum subsp. *microphyllum*	-	-	-	-	-	-	19	11	-	-	-	-	-	-	-	-	-	-	4
Chenopodium desertorum subsp. *rectum*	-	-	-	-	-	-	13	22	-	-	-	-	-	-	-	-	-	-	4
Chenopodium melanocarpum ^{NH}																			
**Chenopodium murale*	-	17	-	40	-	-	-	-	-	-	-	-	-	-	-	-	X	-	3
Chenopodium nitrariaceum	100	17	-	-	-	-	-	-	-	-	-	20	-	100	50	-	-	-	8
Chenopodium pumilio	-	17	-	-	-	-	-	-	-	-	-	-	50	33	25	-	-	-	4
❖*Dissocarpus biflorus* var. *biflorus*	-	-	7	-	-	-	-	-	-	8	-	40	-	-	25	17	-	-	6
Dissocarpus paradoxus	-	67	87	40	100	-	19	22	82	77	67	60	50	X	25	83	33	33	54
Dysphania glomulifera subsp. *eremaea*	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	1
Einadia nutans subsp. *nutans*	100	67	7	20	-	100	-	22	9	8	-	-	-	-	50	-	-	33	16
Enchylaena tomentosa	100	67	100	60	100	100	19	67	64	8	33	-	-	-	25	-	33	-	44
❖*Maireana aphylla*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	1
Maireana appressa	-	-	7	-	-	-	-	11	X	15	33	20	-	-	25	-	-	-	6
Maireana brevifolia	-	33	13	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Maireana erioclada ^{BR}																			
Maireana georgei	-	-	-	-	-	-	-	-	-	X	X	X	-	-	X	X	-	-	-
Maireana microcarpa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	1

Family/Species	**F 1**	**W 2**	**W 4**	**W 16**	**W 17**	**W 29**	**M 3a**	**M 3b**	**M 3d**	**S 8**	**S 8p**	**S 11**	**S 12**	**S 18**	**S 19**	**S 22**	**S 30**	**G 13**	**A All**
Maireana ovata NH																			
Maireana pentatropis	-	-	13	-	-	-	6	33	36	-	-	-	-	-	-	-	-	-	9
Maireana pyramidata	-	33	27	20	50	-	-	-	9	100	100	20	50	-	100	17	33	-	30
Maireana radiata	-	-	-	-	-	-	X	11	-	-	-	-	-	-	-	-	-	-	1
Maireana schistocarpa NH																			
Maireana sclerolaenoides	-	-	33	-	50	-	13	33	27	15	-	-	-	-	-	-	-	-	15
Maireana sedifolia	-	-	7	-	-	-	-	-	-	15	100	-	-	-	-	-	-	-	6
Maireana trichoptera	-	-	-	-	-	-	6	11	-	-	-	-	-	-	-	-	-	-	2
❖*Maireana triptera*	-	17	47	-	-	-	44	56	64	-	-	-	-	-	-	-	-	-	25
Maireana turbinata	-	-	7	-	50	-	-	-	9	8	-	-	-	-	-	-	33	-	5
❖*Malacocera tricornis*	-	-	-	-	-	-	-	-	-	15	-	40	-	-	-	17	-	-	5
❖*Neobassia proceriflora*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	1
Osteocarpum acropterum var. *deminuta*	-	67	-	-	-	-	-	-	-	38	33	60	X	-	75	33	-	-	16
Rhagodia spinescens	-	50	13	-	50	50	-	11	-	46	33	20	-	-	50	-	33	33	18
❖*Rhagodia ulicina*	-	-	13	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	2
Salsola kali	-	67	47	60	50	-	25	44	46	23	33	-	-	100	50	67	100	-	40
Scleroblitum atriplicinum NH																			
Sclerolaena bicornis var. *bicornis*	-	17	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Sclerolaena brachyptera	-	50	7	-	-	-	-	-	-	69	67	100	X	-	-	33	33	-	21
Sclerolaena calcarata	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
❖*Sclerolaena convexula*	-	-	-	-	-	100	6	-	-	-	-	-	-	-	-	-	-	-	3

Family/Species	**F** **1**	**W** **2**	**W** **4**	**W** **16**	**W** **17**	**W** **29**	**M** **3a**	**M** **3b**	**M** **3d**	**S** **8**	**S** **8p**	**S** **11**	**S** **12**	**S** **18**	**S** **19**	**S** **22**	**S** **30**	**G** **13**	**A** **All**
❖*Sclerolaena decurrens* NH																			
Sclerolaena diacantha	-	33	53	20	50	-	75	100	64	23	33	-	-	-	-	33	-	-	42
Sclerolaena divaricata	-	-	-	-	-	-	-	-	-	31	-	20	50	-	50	17	33	-	9
Sclerolaena intricata	-	-	-	-	-	-	-	-	-	8	-	20	50	-	25	17	-	-	5
❖*Sclerolaena lanicuspis*	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	2
Sclerolaena muricata var. *muricata*	100	50	-	-	-	-	-	-	-	8	-	20	50	67	25	X	33	33	12
Sclerolaena muricata var. *semiglabra*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	1
Sclerolaena muricata var. *villosa*	-	-	-	-	-	-	-	-	-	-	-	20	-	33	-	17	-	-	3
Sclerolaena obliquicuspis	-	-	93	20	100	50	31	44	82	38	33	20	-	-	-	-	-	-	39
Sclerolaena parviflora	-	-	-	-	-	-	63	56	18	-	-	-	-	-	-	-	-	-	16
Sclerolaena patenticuspis	-	33	20	-	50	-	-	-	27	38	-	40	-	-	-	-	-	-	15
Sclerolaena stelligera	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	2
Sclerolaena tricuspis	-	17	-	20	-	-	-	-	-	38	-	80	50	-	25	67	33	100	19
❖*Sclerolaena ventricosa*	-	17	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	3
Sclerostegia tenuis	-	-	-	-	-	-	-	-	-	X	-	60	100	-	50	-	-	33	7
Chloanthaceae																			
Dicrastylis verticillata	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
Colchicaceae																			
Wurmbea dioica subsp. *dioica*	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Convolvulaceae																			
Convolvulus erubescens	-	17	-	-	-	-	-	-	-	31	-	-	-	-	-	33	-	-	6

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
◆*Evolvulus alsinoides* var. *decumbens*	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Crassulaceae																			
Crassula colorata var. *acuminata*	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Crassula sieberiana BR																			
Cucurbitaceae																			
**Citrullus colocynthis* BR																			
**Cucumis myriocarpus*	-	50	-	60	-	50	-	-	-	15	33	-	-	-	25	50	33	-	14
Cupressaceae																			
❖*Callitris glaucophylla*	-	-	27	100	-	50	-	X	X	X	-	-	-	-	-	-	X	-	9
Callitris gracilis subsp. *murrayensis*	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[*C. preissii* subsp. *murrayensis*]																			
Callitris verrucosa	-	-	-	-	-	-	6	11	-	-	-	-	-	-	-	-	-	-	2
[*C. preissii* subsp. *verrucosa*]																			
Cyperaceae																			
❖*Eleocharis pallens* BR																			
Isolepis australiensis	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Schoenus subaphyllus	-	-	-	20	-	-	19	11	-	-	-	-	-	-	-	-	-	-	5
Dilleniaceae																			
Hibbertia virgata subsp. *virgata*	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	2
Euphorbiaceae																			
Beyeria opaca	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1
Chamaesyce drummondii	50	17	-	20	-	100	13	-	9	38	-	-	-	-	-	17	-	-	13

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
◆*Chamaesyce* species B	-	-	-	-	-	-	-	-	-	8	33	-	-	-	25	50	-	-	6
❖*Euphorbia planiticola*	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	67	-	-	5
Phyllanthus fuernrohrii	-	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-	2
Poranthera microphylla NH																			
Fabaceae–Caesalpinioideae																			
Senna artemisioides nothosubsp. *coriacea*	-	-	47	X	-	-	-	11	-	-	-	-	-	-	-	-	-	-	7
Senna artemisioides subsp. *filifolia* NH																			
Senna artemisioides subsp. *petiolaris*	-	-	7	-	-	-	-	22	-	-	-	-	-	-	-	-	-	-	3
Senna artemisioides nothosubsp. *sturtii*	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Senna artemisioides subsp. *zygophylla*	-	-	13	-	-	-	13	22	9	-	-	-	-	-	-	-	-	-	6
Fabaceae–Faboideae																			
❖*Bossiaea walkeri*	-	-	-	-	-	-	25	22	-	-	-	-	-	-	-	-	-	-	6
Daviesia arenaria	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1
Daviesia ulicifolia NH																			
❖*Eutaxia microphylla*	-	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-	-	-	2
❖*Glycine canescens*	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
**Medicago laciniata* NH																			
**Medicago minima*	-	17	-	20	-	50	-	-	-	15	-	-	-	-	-	33	33	-	7
**Medicago polymorpha*	50	-	-	-	50	-	-	-	18	38	33	40	-	33	50	-	33	33	16
**Medicago praecox*	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	1
**Medicago truncatula*	-	-	-	20	-	50	-	-	9	15	-	-	-	-	-	X	33	-	6

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
Swainsona burkittii^{BR}																			
❖*Swainsona greyana*	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
❖*Swainsona phacoides*	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
**Templetonia egena*^{NH}																			
**Vicia sativa* subsp. *angustifolia*	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Fabaceae–Mimosoideae																			
★❖*Acacia acanthoclada*^{NH}																			
Acacia aneura	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Acacia brachybotrya	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-
Acacia burkittii	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Acacia cambagei^{NH}																			
✱★❖*Acacia carnei*^{NH}																			
❖*Acacia colletioides*	-	-	X	-	-	-	13	67	-	-	-	-	-	-	-	-	-	-	7
Acacia continua^{NH}																			
Acacia halliana^{NH}																			
Acacia homalophylla	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Acacia ligulata	-	-	X	-	-	-	13	X	-	-	-	-	-	-	-	-	X	-	2
❖*Acacia loderi*	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
❖*Acacia melvillei*	-	-	X	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Acacia montana^{NH}																			
Acacia murrayana^{NH}																			
❖*Acacia oswaldii*	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1

Family/Species	**F** **1**	**W** **2**	**W** **4**	**W** **16**	**W** **17**	**W** **29**	**M** **3a**	**M** **3b**	**M** **3d**	**S** **8**	**S** **8p**	**S** **11**	**S** **12**	**S** **18**	**S** **19**	**S** **22**	**S** **30**	**G** **13**	**A** **All**
Acacia rigens	-	-	-	-	-	-	25	11	-	-	-	-	-	-	-	-	-	-	5
Acacia salicina	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia sclerophylla var. *sclerophylla* NH																			
Acacia stenophylla	100	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Acacia victoriae	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	1
Acacia wilhelmiana	-	-	-	-	-	-	63	33	-	-	-	-	-	-	-	-	-	-	12
Fumariaceae																			
**Fumaria muralis* MW																			
Gentianaceae																			
Centaurium spicatum BR																			
Geraniaceae																			
**Erodium cicutarium*	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	17	-	33	2
Erodium crinitum	-	-	-	40	-	100	-	11	9	23	33	-	-	-	-	33	-	-	11
Goodeniaceae																			
Goodenia cycloptera NH																			
Goodenia fascicularis	-	33	-	-	-	100	-	-	-	8	-	-	-	-	-	-	33	-	6
Goodenia heteromera	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Goodenia pinnatifida NH																			
Goodenia pusilliflora NH																			
Goodenia varia	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	1
Goodenia willisiana NH																			

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
✣*Scaevola depauperata*	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	1
Gyrostemonaceae																			
Codonocarpus cotinifolius	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	2
✱★✣*Codonocarpus pyramidalis* ^{NH}																			
✣*Gyrostemon australasicus* ^{NH}																			
Haloragaceae																			
✣*Haloragis glauca* forma *glauca*	-	17	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	2
Haloragis odontocarpa	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Myriophyllum verrucosum	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Juncaceae																			
**Juncus bufonius* ^{BR}																			
Juncus flavidus	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Juncaginaceae																			
Triglochin calcitrapum ^{BR}																			
Lamiaceae																			
Ajuga australis ^{NH}																			
**Marrubium vulgare*	-	-	-	20	-	X	-	-	-	-	-	-	-	-	X	-	-	-	1
Prostanthera striatiflora ^{NH}																			
**Salvia verbenaca*	-	-	7	-	100	50	6	-	-	15	-	-	-	-	-	-	X	-	6
Teucrium albicaule	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Teucrium racemosum	50	17	-	-	-	-	-	-	-	-	-	20	-	67	-	-	-	-	5

Family/Species	F	W	W	W	W	W	M	M	M	S	S	S	S	S	S	S	S	G	A
	1	2	4	16	17	29	3a	3b	3d	8	8p	11	12	18	19	22	30	13	All
Westringia rigida	-	-	-	-	-	-	-	11	18	-	-	-	-	-	-	-	-	-	3
Lauraceae																			
Cassytha melantha	-	-	-	-	-	-	13	-	9	-	-	-	-	-	-	-	-	-	3
Linaceae																			
Linum marginale^{BR}																			
Lobeliaceae																			
Pratia concolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	-	-	1
Loganiaceae																			
Logania nuda^{NH}																			
Lomandraceae																			
Lomandra collina^{NH}																			
Lomandra effusa	-	-	-	-	-	-	6	11	-	-	-	-	-	-	-	-	-	-	2
Lomandra glauca^{BR}																			
Lomandra leucocephala subsp. *robusta*	-	-	-	-	-	-	44	11	-	-	-	-	-	-	-	-	X	-	7
Loranthaceae																			
❖*Amyema linophyllum* subsp. *orientale*^{NH}																			
Amyema miquelii	50	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Amyema miraculosum subsp. *boormanii*	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Amyema preissii^{NH}																			
Amyema quandang^{NH}																			
Lysiana exocarpi subsp. *exocarpi*	50	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Lysiana exocarpi subsp. *tenuis*	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
Lysiana linearifolia NH																			
Malvaceae																			
◆❖*Abutilon fraseri*	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Abutilon halophilum	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Abutilon otocarpum BR																			
Hibiscus krichauffianus	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
**Hibiscus trionum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	2
Lavatera plebeia BR																			
**Malva parviflora*	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	33	2
❖*Radyera farragei*	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Sida corrugata NH																			
Sida cunninghamii	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Sida filiformis NH																			
Sida intricata	-	17	7	-	-	100	-	-	9	8	-	-	-	-	25	-	-	-	6
Sida trichopoda	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-	17	-	-	3
Marsileaceae																			
Marsilea drummondii	50	17	-	-	-	-	-	-	-	-	-	20	-	67	-	-	-	-	5
Myoporaceae																			
❖*Eremophila deserti*	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	1
Eremophila glabra	-	-	-	-	-	-	19	56	-	-	-	-	-	-	-	-	-	-	7
Eremophila longifolia	-	-	7	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	2
❖*Eremophila maculata*	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Family/Species	**F**	**W**	**W**	**W**	**W**	**W**	**M**	**M**	**M**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**G**	**A**
	1	**2**	**4**	**16**	**17**	**29**	**3a**	**3b**	**3d**	**8**	**8p**	**11**	**12**	**18**	**19**	**22**	**30**	**13**	**All**
❖*Eremophila oppositifolia* $^{\text{NH}}$																			
❖*Eremophila sturtii*	-	-	33	-	100	-	X	-	18	-	-	-	-	-	-	-	-	-	8
Myoporum montanum	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myoporum platycarpum subsp. *platycarpum*	-	-	40	-	-	-	6	33	18	-	-	-	-	-	-	-	-	-	11
Myrtaceae																			
Eucalyptus camaldulensis	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Eucalyptus costata	-	-	-	-	-	-	31	44	X	-	-	-	-	-	-	-	-	-	8
Eucalyptus dumosa	-	-	7	-	-	-	63	89	73	-	-	-	-	-	-	-	-	-	25
Eucalyptus dumosa × socialis	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1
Eucalyptus gracilis	-	-	-	-	-	-	25	67	64	-	-	-	-	-	-	-	-	-	16
Eucalyptus intertexta	-	-	X	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Eucalyptus largiflorens	50	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Eucalyptus leptophylla	-	-	X	-	-	-	44	33	-	-	-	-	-	-	-	-	-	-	9
Eucalyptus oleosa	-	-	-	-	-	-	19	33	18	-	-	-	-	-	-	-	-	-	7
Eucalyptus oleosa × socialis	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	1
Eucalyptus populnea subsp. *bimbil* $^{\text{NH}}$																			
❖*Eucalyptus porosa* $^{\text{NH}}$																			
Eucalyptus socialis	-	-	7	-	-	-	94	89	91	-	-	-	-	-	-	-	-	-	31
Leptospermum coriaceum	-	-	-	-	-	-	25	11	-	-	-	-	-	-	-	-	-	-	5
Nyctaginaceae																			
Boerhavia dominii	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	33	-	2
Oleaceae																			

Family/Species	F	W	W	W	W	W	M	M	M	S	S	S	S	S	S	S	S	G	A
	1	2	4	16	17	29	3a	3b	3d	8	8p	11	12	18	19	22	30	13	All
Jasminum lineare	-	-	7	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	2
Orchidaceae																			
Pterostylis biseta ^{NH}																			
Oxalidaceae																			
Oxalis perennans	50	17	-	-	-	50	-	-	9	-	-	-	-	-	-	-	-	33	5
**Oxalis pes-caprae* ^{NH}																			
Phormiaceae																			
Dianella revoluta var. *revoluta*	-	-	X	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1
Pittosporaceae																			
Pittosporum phylliraeoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Plantaginaceae																			
Plantago cunninghamii	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1
Plantago drummondii	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	33	-	2
Plumbaginaceae																			
**Limonium lobatum* ^{BR}																			
Poaceae																			
Agrostis avenacea var. *avenacea*	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	2
**Alopecurus geniculatus*	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Aristida contorta	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	2
**Avena fatua*	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Bromus arenarius ^{NH}																			

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
**Bromus rubens*	50	17	-	-	-	-	-	-	9	-	-	-	-	-	-	-	33	-	4
**Bromus tectorum* NH																			
Chloris truncata	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	33	-	2
Cynodon dactylon	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	1
❖*Dactyloctenium radulans*	50	17	-	20	-	-	-	-	-	15	-	-	-	-	-	17	-	-	6
Danthonia caespitosa	-	17	7	-	-	-	-	-	-	33	-	-	-	X	-	33	-	-	6
Danthonia setacea	-	-	7	-	-	-	-	X	-	8	-	20	-	-	-	-	-	-	3
◆❖*Digitaria ammophila*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Digitaria brownii	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Elymus scaber NH																			
Enneapogon avenaceus	-	-	7	20	-	50	-	-	-	31	67	-	-	-	-	-	33	-	9
Enteropogon acicularis	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Eragrostis australasica	-	-	-	-	-	-	-	-	-	8	-	20	50	X	25	-	-	100	6
Eragrostis eriopoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	33	2
Eragrostis setifolia	-	17	-	-	-	-	-	-	-	31	-	-	-	-	-	-	-	-	5
Homopholis proluta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	1
**Hordeum leporinum*	-	50	-	40	-	50	-	-	18	23	33	20	-	67	25	50	33	33	19
**Hordeum marinum* NH																			
**Lamarckia aurea*	-	-	-	-	-	50	-	-	-	8	-	-	50	-	25	-	33	-	5
❖*Panicum decompositum*	-	-	-	-	-	-	-	-	-	8	-	-	-	33	-	50	-	-	5
Panicum effusum	100	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	3

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
Panicum laevinode	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	1
**Parapholis incurva* ^{NH}																			
Paspalidium constrictum	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Paspalidium jubiflorum	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
**Phalaris paradoxa* ^{BR}																			
Poa fordeana ^{NH}																			
**Rostraria pumila* ^{NH}																			
**Schismus barbatus* ^{NH}																			
◆❖*Sporobolus caroli*	-	17	-	-	-	-	-	-	-	15	-	-	-	-	25	-	-	-	4
Stipa acrociliata ^{NH}																			
Stipa blackii ^{NH}																			
Stipa drummondii ^{NH}																			
Stipa elegantissima ^{NH}																			
Stipa eremophila ^{NH}																			
Stipa nitida	-	17	67	40	100	-	63	89	82	77	67	40	-	33	-	17	67	-	55
Stipa nodosa	-	33	-	-	-	50	-	-	-	8	-	20	-	-	-	-	-	X	5
❖*Stipa puberula* ^{NH}																			
Stipa scabra subsp. *scabra* ^{NH}																			
❖*Stipa tuckeri* ^{NH}																			
❖*Tragus australianus*	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	1
Triodia scariosa subsp. *scariosa*	-	-	-	20	-	-	100	100	18	-	-	-	-	-	-	-	33	-	26
❖*Triraphis mollis*	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	33	-	1

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
**Vulpia bromoides* ^{NH}																			
**Vulpia muralis* ^{NH}																			
**Vulpia myuros*	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Polygonaceae																			
**Acetosa vesicaria* ^{NH}																			
**Emex australis* ^{NH}																			
✣*Muehlenbeckia diclina* ^{NH}																			
Muehlenbeckia florulenta	100	33	-	-	-	-	-	-	-	-	-	-	-	67	-	17	-	33	7
Polygonum plebeium	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	1
Rumex brownii	50	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
**Rumex crispus* ^{NH}																			
**Rumex tenax* ^{NH}																			
Portulacaceae																			
Calandrinia calyptrata ^{NH}																			
✣*Calandrinia disperma* ^{NH}																			
Calandrinia eremaea	-	-	X	20	-	-	-	-	X	-	-	-	-	-	-	-	-	33	2
Portulaca oleracea	-	-	-	-	-	-	-	-	-	-	-	-	50	-	-	-	-	-	1
Proteaceae																			
Grevillea huegelii	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	1
✣*Grevillea pterosperma*	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
✣*Hakea leucoptera*	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Family/Species	F	W	W	W	W	W	M	M	M	S	S	S	S	S	S	S	S	G	A
	1	2	4	16	17	29	3a	3b	3d	8	8p	11	12	18	19	22	30	13	All
❖*Hakea tephrosperma*	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ranunculaceae																			
Clematis microphylla var. *microphylla* NH																			
Myosurus minimus var. *australis* BR																			
Ranunculus pentandrus var. *platycarpus* BR																			
Ranunculus pumilio var. *pumilio*	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Rhamnaceae																			
Cryptandra propinqua NH																			
Rubiaceae																			
❖*Opercularia turpis*	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-
Rutaceae																			
❖*Boronia caerulescens* NH																			
❖*Eriostemon difformis* subsp. *difformis* NH																			
Eriostemon linearis	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Flindersia maculosa	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
❖*Geijera parviflora*	-	-	40	-	-	X	X	-	-	-	-	-	-	-	-	-	X	-	6
Santalaceae																			
Exocarpos aphyllus	-	17	13	-	-	X	-	11	-	-	-	-	-	-	-	-	-	-	4
❖*Exocarpos sparteus*	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1
❖*Santalum acuminatum*	-	-	-	-	-	-	6	11	-	-	-	-	-	-	-	-	-	-	2
★❖*Santalum murrayanum*	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-

Family/Species	F 1	W 2	W 4	W 16	W 17	W 29	M 3a	M 3b	M 3d	S 8	S 8p	S 11	S 12	S 18	S 19	S 22	S 30	G 13	A All
Sapindaceae																			
⁘*Alectryon oleifolius* subsp. *canescens*	-	-	93	40	-	X	X	-	X	-	-	-	-	-	-	-	33	-	16
Dodonaea bursariifolia	-	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-	-	-	2
Dodonaea viscosa subsp. *angustissima*	-	-	13	-	-	-	56	89	18	-	-	-	-	-	-	-	100	-	22
Scrophulariaceae																			
Limosella australis ^{NH}																			
Stemodia florulenta	-	17	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	2
**Veronica peregrina*																			
Simaroubaceae																			
**Ailanthus altissima* ^{BR}																			
Sinopteridaceae																			
◆*Cheilanthes distans*	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-
⁘◆⁘*Cheilanthes lasiophylla*	-	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-	2
Cheilanthes sieberi subsp. *sieberi*	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	1
Solanaceae																			
Duboisia hopwoodii	-	-	7	X	-	-	25	11	9	-	-	-	-	-	-	-	-	-	6
Lycium australe	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	1
**Lycium ferocissimum*	50	17	-	-	-	50	-	-	-	-	-	-	-	-	25	-	-	-	4
**Nicotiana glauca*	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	33	-	2
Nicotiana occidentalis subsp. *obliqua* ^{NH}																			
Nicotiana velutina	-	33	-	40	-	50	-	-	-	-	-	-	-	-	-	-	-	-	5

Family/Species	F	W	W	W	W	W	M	M	M	S	S	S	S	S	S	S	S	G	A
	1	2	4	16	17	29	3a	3b	3d	8	8p	11	12	18	19	22	30	13	All
❖*Solanum coactiliferum*	-	-	-	-	-	-	13	-	9	8	-	-	-	-	-	-	-	-	4
Solanum esuriale	-	50	-	20	-	50	13	22	9	15	-	-	-	33	-	-	-	-	12
Solanum ferocissimum	-	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-	2
✱★❖*Solanum karsense* NH																			
Solanum nigrum NH																			
Thymelaeaceae																			
Pimelea microcephala subsp. *microcephala*	-	-	-	-	-	-	6	11	-	-	-	-	-	-	-	-	-	-	2
❖❖*Pimelea simplex* subsp. *continua*	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1
Pimelea trichostachya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	1
Typhaceae																			
Typha domingensis	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Urticaceae																			
Parietaria debilis MW																			
**Urtica urens*	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Verbenaceae																			
**Verbena officinalis*	-	-	-	-	-	-	-	-	-	-	-	-	-	33	25	-	-	-	2
**Verbena supina*	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Zygophyllaceae																			
Nitraria billardierei	-	-	X	-	-	-	-	-	-	54	33	40	50	-	25	17	-	33	13
**Tribulus terrestris*	-	17	-	-	-	-	-	-	-	-	-	-	-	33	-	33	-	-	4
Zygophyllum ammophilum NH																			

Family/Species	**F**	**W**	**W**	**W**	**W**	**W**	**M**	**M**	**M**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**G**	**A**
	1	**2**	**4**	**16**	**17**	**29**	**3a**	**3b**	**3d**	**8**	**8p**	**11**	**12**	**18**	**19**	**22**	**30**	**13**	**All**
Zygophyllum angustifolium NH																			
Zygophyllum apiculatum	-	33	-	-	-	-	6	44	46	-	-	-	-	-	-	17	-	-	12
Zygophyllum aurantiacum	-	-	-	-	-	-	-	22	9	-	-	-	-	-	-	-	-	-	3
❖*Zygophyllum crenatum* NH																			
Zygophyllum eremaeum	-	-	27	-	-	-	-	22	18	-	-	-	-	-	-	-	-	-	7
Zygophyllum glaucum	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	1
Zygophyllum iodocarpum	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	17	-	-	2
Zygophyllum ovatum NH																			
Zygophyllum simile NH																			

Floristics and vegetation patterns of Coolah Tops, New South Wales

D.L. Binns

Binns, D.L. (State Forests of NSW PO Box J19 Coffs Harbour Jetty, NSW, Australia 2450) 1997. Floristics and vegetation patterns of Coolah Tops, New South Wales. Cunninghamia *5(1): 233–274.*The vascular vegetation of Coolah Tops, a relatively isolated basalt plateau (latitude 31°41' to 31°15' S, longitude 149°58' to 150°15'E), is described from fifty randomly located plots distributed throughout the range of vegetation types and physical environments and representing the range of forest management histories. This area was formerly State Forest but is now included mostly within Coolah Tops National Park. Floristic data are analysed using classification and ordination. The floristic composition, structure and environment of twenty-two floristic communities are described. The vegetation is predominantly grassy open forest with *Eucalyptus laevopinea, Eucalyptus nobilis, Eucalyptus pauciflora* and *Eucalyptus dalrympleana* subsp. *heptantha* as the most common canopy dominants. A list of 316 native and thirty-seven naturalised taxa is presented, with frequency of occurrence in broad floristic groups. The vascular flora is of relatively low diversity and only four species are regarded as being of conservation significance, although a further two nationally significant species may occur in the area. Altitude and past grazing history (which is correlated with altitude) have the most influence on vegetation patterns, with topography and past logging history contributing least.

Introduction

Coolah Tops is an elevated and relatively isolated basalt plateau, up to 1250 m altitude and mostly exceeding 1000 m, bounded approximately by latitude 31°41' to 31°15'S and longitude 149°58' to 150°15'E. It forms a south-westerly extension of the New South Wales Northern Tablelands (Anderson 1961), at the junction of the Warrumbungle and Liverpool Ranges, north-east of Coolah. It is bounded by flat to undulating, predominantly cleared grazing lands to the south and west, but partially forested ranges extend to the north and east. The study area (Fig. 1) is the former Warung and Bundella State Forests, a contiguous area of about 13 000 ha which, except for small areas held as Crown Lease, are now included in Coolah Tops National Park. The area has been used for rough grazing since early this century and for commercial timber harvesting since at least 1941 (Forestry Commission of NSW 1982), although there is evidence of some logging, ringbarking and partial clearing being carried out prior to this by local landholders.

Although there is broad-scale regional information on vegetation available, there appear to have been no vegetation studies of Coolah Tops published, and no floristic data from the area are listed in recent reviews (Bryant & Benson 1981, Keith 1988, Benson & Melrose 1993). At a regional level, McRae & Cooper (1985) describe the vegetation of the Merriwa area, their study area being immediately adjacent and to the south of Coolah Tops. However, the habitats have little in common, with only minor overlap along the southern foothills of Liverpool Range. Fisher (1985) has described the rainforests of Liverpool Range, but these all occur further east (the most westerly at 150°30'E) and, for dominants at least, have little in common with the most mesic vegetation at Coolah Tops. Benson and Andrew (1990) report on the flora and fauna of the former Ben Halls Gap State Forest (now Ben Halls Gap National Park) on the eastern end of the Liverpool Range, which is also on basalt at a similar altitude (up to 1370 m) and supports some similar floristic assemblages. A floristic list for Coolah Tops has been previously compiled and is included in the Management Plan (Forestry Commission of NSW 1982). However, the source for these records is unknown and locality details are not given. It is uncertain whether all records are strictly from the previous State Forests, or whether some may be from adjacent private property. Specimens in the National Herbarium of New South Wales indicate that there have been periodic collections from the area, especially in the vicinity of Norfolk Falls, in the former Norfolk Falls Flora Reserve.

This paper describes the terrestrial vascular flora of the area, particularly the vegetation types and distribution, habitat and abundance of plant species, identifies vascular plant species and communities of conservation significance and assesses the influence of past management and other environmental factors on floristic patterns. The survey data which forms the basis of this paper was originally collected for State Forests of New South Wales as part of an Environmental Impact Statement for a proposal to continue logging in the area.

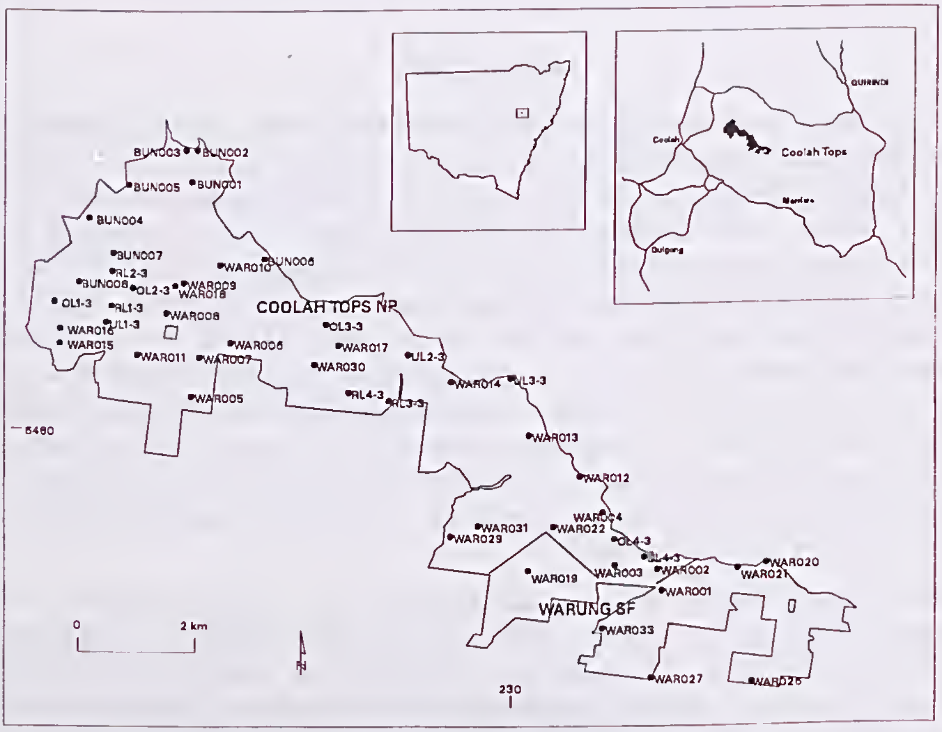

Fig. 1. Location of Coolah Tops study area and flora survey plots (•).

Methods

Sampling strategy and plot location

Floristic data were derived from non-permanent plots established within the study area to sample the full range of Forest Types (Forestry Commission of New South Wales 1989) mapped in the area, and to sample the range of physical habitats and management histories. Particular attention was also given to sampling or at least inspecting unusual or restricted habitats (e.g. rock outcrops, swamps, riparian habitats). Plots in more extensive types were randomly selected but constrained to be within 500 m of road access or in areas which could be sampled en route to those in restricted or unusual habitat types. Plots in restricted or unusual types were not constrained by proximity to roads. This strategy was designed to ensure efficient sampling of the full range of types and habitats while reducing unproductive travelling time as far as possible.

In the field, plots were positioned as far as possible within a relatively homogeneous patch of vegetation. The standard size was a 50 m × 20 m (0.1 ha) rectangle, although some habitats required a variation in shape to ensure homogeneity within one plot e.g. longer and narrower plots, up to 100 m × 10 m, were used for riparian vegetation.

A total of fifty plots, including those on fauna survey transects, was surveyed during the present survey. Approximate locations of all survey plots are shown in Fig. 1. The majority (thirty-nine plots) were surveyed during 23 February–1 March 1993, with additional plots surveyed in September 1993 and May 1994. Plot locations and survey dates are listed in Appendix 2. Table 1 shows the distribution of plots among combinations of two major environmental factors, altitude and degree of topographic exposure, to assess the extent to which the sampling strategy based primarily on mapped forest types has covered the range of environmental variation. Lithology is not included as a factor since the area is uniformly on basalt. The plots are well distributed across the range of these environmental factors, but the lowest altitude class is relatively over-sampled (these are potentially of most conservation significance due to past clearing) and the 800–1000 m class relatively undersampled (these are the steeper slopes, least likely to be affected by forest management activities planned at the time of the survey).

Floristic and structural data

All vascular plant species which could be distinguished within a plot were recorded and a cover-abundance code estimated for each species within each vertical stratum, and for all strata combined. Codes are based on projected canopy cover, as follows: 1 = < 5%, few individuals; 2 = < 5%, any number of individuals; 3 = 6–25%; 4 = 26–50%; 5 = 51–75%; 6 = > 75%. Taxonomy and nomenclature follow the National Herbarium of NSW. This is mostly as published in Harden (1990–1993), except where more recent revisions have been published. Voucher specimens of many species were collected from the area and are retained at the State Forests Research Division herbarium at West Pennant Hills. In a few cases, where difficulties were encountered in identification, specimens were referred to specialists at the National Herbarium of

Table 1. Distribution of flora survey plots among combinations of altitude and degree of topographic exposure.

The latter is categorised as: EXP=exposed (ridge crests and northerly aspects); MOD=moderate (flat areas and easterly and westerly slopes); SHL=sheltered (riparian and southerly slopes). Exp. no. is the number of plots which would be allocated to that combination if approximately 50 plots were distributed evenly across all combinations.

Altitude (m)	Degree of top. exp	Area (ha)	No. Plots	Exp. no. plots
600–800	EXP	111	1	1
	MOD	326	3	1
	SHL	142	2	1
800–1000	EXP	533	1	2
	MOD	1154	1	5
	SHL	924	5	4
1000–1200	EXP	2040	5	8
	MOD	4355	18	17
	SHL	2861	13	11
>1200	all	227	1	1

NSW for determination. For all trees with stem diameter at breast height (1.3 m) greater than 10 cm, the number of stems of each species was recorded by 10 cm diameter classes, up to 50 cm. Diameter was measured for all stems over 50 cm. These data were used to calculate an estimate of basal area by tree species for each plot. All stumps were similarly recorded and the data used to give a measure of logging intensity within the plot. Slope, altitude, aspect, topographic position, drainage, percentage cover and particle size of surface rock and cover of outcropping bedrock were recorded. An assessment was made of previous disturbance by logging, fire and grazing, on the basis of any available visual evidence. An estimate of intensity and time since disturbance was recorded.

Field work was carried out mostly in late summer. Some ephemeral species may have been overlooked, and spring flowering geophytes, including Orchidaceae, would have been generally overlooked. Although these may be a significant component of the total flora, they normally form a minor component of forest vegetation in NSW and their omission is not expected to affect the community analysis. Some species, especially monocotyledons, may have been overlooked due to absence of active growth or vegetative similarity to common species. No attempt was made to sample soil-stored seed. No detailed survey of naturalised species along roads (i.e. within 5 m of the road pavement) was undertaken, but such species were noted if they were common, or also occurred in nearby forest. The total number of naturalised species is likely to be understated as a result, but the survey reflects the relative importance of the naturalised component in the vegetation generally and the likely future invasion potential.

Data analysis

Floristic data were classified into vegetation communities by grouping floristically similar plots using a numerical hierarchical agglomerative classification process, using the Bray-Curtis association measure and a flexible UPGMA sorting strategy with beta = 0.0 (FUSE module of the PATN package, Belbin 1994). A beta value of zero was chosen to yield a 'space-conserving' fusion strategy which does not exaggerate floristic differences between groups. Communities were defined at dissimilarity levels of 0.6 and 0.8, which provide a reasonable reflection of what are perceived as plant communities in the field.

The analysis of a full floristic data set, including all strata, implicitly assumes that the overstorey and the various understorey strata respond similarly to environmental factors, and at similar spatial and temporal scales. In fact, this is unlikely to be the case. For example, at the extreme, canopy trees respond to environmental factors at a much broader scale than herbs in the lowest understorey stratum and the latter are much more likely to reflect recent disturbance events (such as fire) to which canopy species are relatively insensitive. Thus an analysis of all strata combined may obscure spatial patterns relating to these variations in responses. However, it is difficult to define limits which realistically and consistently allow separate analyses of strata across a range of vegetation types, and any defined limits are essentially arbitrary. In practice, an analysis of all species combined tends to be dominated by the influence of lower strata species, which usually contribute more than the canopy species to the overall floristic characterisation of a plot. To allow consideration of these interactions, three separate analyses were performed and compared: 1. Basal area of all stems >10 cm diameter was used to define overstorey communities; 2. Total cover of all species was used for a full floristic analysis; 3. Cover of understorey species (i.e. excluding canopy species which were defined as those with stem diameter > 10 cm) was used for an understorey analysis. As only cover-abundance codes were recorded for understorey floristic data, these were converted to percentages for analyses 2 and 3, as the mid-point of the cover class for cover > 5 per cent and using 1 per cent and 3 per cent for codes 1 and 2 respectively.

For examination of logging impact and the influence of other environmental factors on plant community floristic composition, the full data matrix was reduced by including in the analysis only the twenty-nine plots which were either previously logged or potentially able to be logged under current precriptions. This also excluded floristically disparate plots in habitats not subject to logging, such as swamps, riparian habitats and steep, rocky habitats. Also, species which occurred in two or fewer such plots were omitted, leaving a matrix of cover codes for 29 sites × 95 species for analysis. Cover codes, rather than mid-point percentages as used for classification, were used to give greater relative weight to the influence of less common species.

A constrained ordination method, Canonical Correspondence Analysis (Ter Brack 1986, 1987) was used for analysis of relationships between floristic composition and environmental factors. This method maximally correlates the arrangement of species and sites along ordination axes, subject to the constraint that the axes are linear combinations of the explanatory variables. Ter Braak (1986) fully describes the underlying assumptions and strengths of this method. The main assumption is that individual species response models are all similar and all of unimodal, Gaussian form. Although it is doubtful whether this assumption is reasonable for all species, CCA has been shown to be robust to moderate violations of assumptions (Palmer 1993). It also has the advantage that the results are unaffected by correlations among environmental variables. In interpreting the ordination diagram, environmental variables are represented by arrows, the length representing the strength of correlation between the environmental variable and the ordination axes, and the direction representing the direction of maximum change of the variable. Species and sites may be then ordered along vectors for environmental variables to indicate floristic trends. Analyses were performed using programs written in Splus (Statistical Science, Inc. version 3.0 1991).

Results

Floristics

A total of 297 native vascular plant taxa and thirty-three naturalised taxa was recorded during the field survey, including 316 from survey plots. Appendix 1 lists these species by family, with their frequency of occurrence by broad floristic group (described below) and logging category. Appendix 1 also includes additional species (nineteen native and four naturalised) previously recorded in the area in the forest Management Plan (Forestry Commission of NSW 1982). While some of these are infrequent or localised species which were overlooked during the present survey, it is curious that

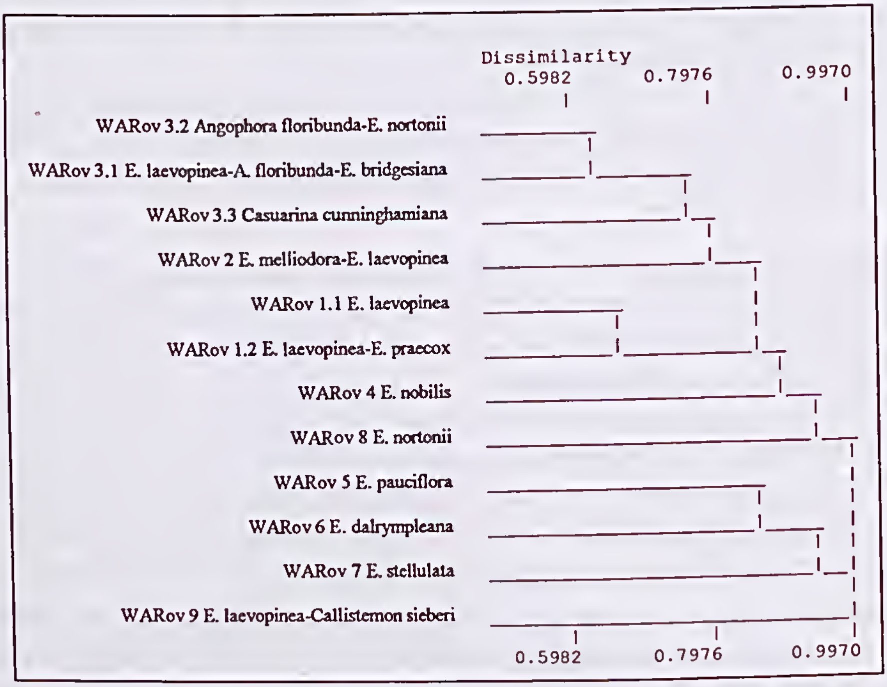
Dissimilarity
0.5982
0.7976
0.9970
WARov 3.2 Angophora floribunda-E. nortonii
WARov 3.1 E. laevopinea-A. floribunda-E. bridgesiana
WARov 3.3 Casuarina cunninghamiana
WARov 2 E. melliodora-E. laevopinea
WARov 1.1 E. laevopinea
WARov 1.2 E. laevopinea-E. praecox
WARov 4 E. nobilis
WARov 8 E. nortonii
WARov 5 E. pauciflora
WARov 6 E. dalrympleana
WARov 7 E. stellulata
WARov 9 E. laevopinea-Callistemon sieberi
0.5982
0.7976
0.9970

Fig. 2. Dendrogram from floristic classification of overstorey basal areas, truncated at the 0.6 dissimilarity level.

Table 2. Summary of distribution of plots among understorey and floristic communities

	Understorey community																			
Floristic community	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	TOT
1																			1	1
2.1																1				1
2.2															1					1
2.3														2						2
2.4													1							1
2.5													1							1
3.1																		1		1
3.2												8								8
3.3						3														3
3.4						1														1
3.5											3									3
3.6										8										8
3.7						2														2
3.8					1	2				1							1			5
4.1						1		2												3
4.2									2											2
4.3							1													1
4.4				1																1
4.5					1															1
4.6			1																	1
5.1		1																		1
5.2	2																			2
TOTAL	2	1	1	1	2	9	1	2	2	9	3	8	2	2	1	1	1	1	1	50

several naturalised exotics were listed as common. Although there are no details for the previous records, these species are most likely to be restricted to highly disturbed habitats adjacent to pasture in private property.

Some specimens could not be confidently determined to species level because of lack of fertile material and vegetative similarity among species, or because of uncertain taxonomic limits within groups. Such difficulties were experienced with the following species or groups: *Geranium potentilloides* / *G. solanderi* / *G. homeanum* / *G. retrorsum*; *Cymbonotus* (all flowering material was *C. preissianus*, but *C. lawsonianus* may have been represented in non-fertile specimens); *Danthonia pilosa / D. racemosa; Gonocarpus humilis* (vegetative material could include *G. tetragynus*); *Hibbertia obtusifolia* (many specimens had characteristics of *H. linearis* and could be regarded as intermediates between these two species); *Poa sieberiana / P. labillardieri; Senecio diaschides / Senecio* species E. *Leptospermum polygalifolium* subsp. *montanum* and *L. gregarium* appeared to intergrade to a considerable extent and some specimens could not be unequivocally assigned to either.

A feature of the survey area is its general uniformity of vegetation structure and floristics, reflected in relatively low overall floristic richness. For example, the floristic richness (316 species in fifty plots) may be compared with that of the predominantly grassy forests of the Mount Royal Management Area, a more coastal area of slightly smaller extent at similar latitude, for which about 395 vascular plant species were recorded from an equivalent number of plots (Shields, York and Binns 1992). This relatively depauperate flora is perhaps surprising considering that the geographical position of the area might lead to an expectation that the flora would be a mixture of both tablelands and western slopes floristic elements. However, because the area is at the extreme western margin of the tablelands, many of the common tablelands species are absent. This is particularly notable among the eucalypts, with some otherwise widespread and abundant northern tablelands species such as *Eucalyptus campanulata* and *Eucalyptus obliqua* apparently absent, and only nine eucalypt species overall. Relatively little of the total recorded diversity is contributed by the steep slopes along the boundary which have a western slopes influence, the plateau grassy forests contributing a total of 216 species to plot data. This is perhaps partly due to increased sampling emphasis on commercial plateau forests and relatively less effort on steeper slopes.

Overstorey and understorey classification

Twelve forest overstorey classes were defined, in nine groups, from classification of tree basal area data. The relationships among these classes is shown by the dendrogram (Fig. 2) and their composition is briefly discussed below in the descriptions of floristic communities.

Nineteen communities in six groups were derived from classification of floristic survey data excluding eucalypts (understorey data), at dissimilarity levels of 0.6 and 0.8 respectively (Fig. 3). The relationship with the full floristic classification (summarised in Table 2) shows that most understorey communities are uniquely correlated with floristic communities, or have only one 'misclassified' plot. The major discrepancy is understorey community 6 which occurs across a range of floristic communities. Understorey community 6 is most strongly characterised by relative abundance of the prostrate herb *Acaena novae-zelandiae*. Its distribution across several floristic communities is due to its association with several distinct overstorey communities and the relatively strong influence of the canopy component over otherwise minor differences in overall floristic composition of these plots. Due to the close correlation between the two classifications, the understorey classification is not further described, and any discrepancies between the two classifications are discussed in the floristic community descriptions below.

Table 3. Summary of distribution of plots among overstorey and floristic communities

	Floristic community																						
		RIPARIAN					PLATEAU GRASSY								DRY SLOPES								
	1	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	4.1	4.2	4.3	4.4	4.5	4.6	5.1	5.2	TOT
Overstorey Community																							
1.1 *E. laevopinea*							1	2	1		3	6		5		1							19
1.2 *E. laevopinea–E. praecox*													2										2
2 *E. melliodora–E. laevopinea*															3		1						4
3.1 *E. laevopinea–Ang. floribunda– E. bridgesiana*		1		1												1							3
3.2 *Angophora floribunda E. nortonii*																				1			1
3.3 *C. cunninghamii*			1																				1
4 *E. nobilis*	1			1				1				1											4
5 *E. pauciflora*								5	1	1		1											8
6 *E. dalrympleana* ssp. *heptantha*					1																1		2
7 *E. stellulata*									1														1
8 *E. nortonii*																		1	1				2
9 *E. laevopinea–C. sieberi*						1																	1
Non-forest																						2	2
TOTAL	1	1	1	2	1	1	1	8	3	1	3	8	2	5	3	2	1	1	1	1	1	2	50

Descriptions of floristic communities

Twenty-two floristic communities in five groups were defined, at the 0.6 and 0.8 levels of dissimilarity, from the classification of all species combined (Fig. 4). Table 3 summarises the relationship between floristic communities and understorey communities, and Table 4 summarises the distribution of floristic communities among overstorey communities. The floristic communities are briefly described below (R denotes floristic richness as number of species per plot, or median floristic richness where there are three or more plots), with comments on the relationships with overstorey communities (summarised in Table 3) and where appropriate, with understorey classes (Table 2).

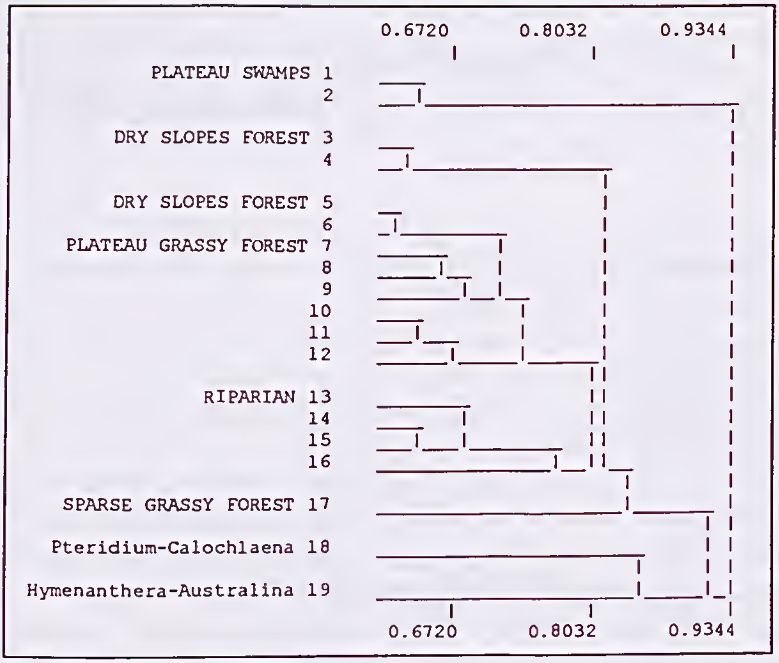

Fig. 3. Dendrogram from floristic classification of cover of understorey species, truncated at the 0.6 dissimilarity level.

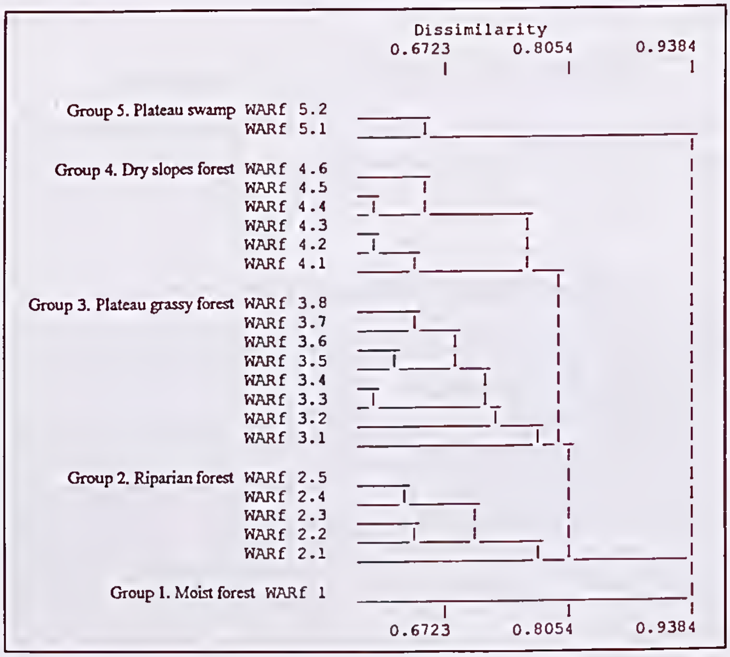

Fig. 4. Dendrogram from floristic classification of cover of all species, truncated at the 0.6 dissimilarity level.

Floristic group 1. Moist forest

1.1 *Hymenanthera dentata–Australina pusilla*
Plot WAR020; R=23

A dense, low forest of *Hymenanthera dentata, Lomatia arborescens* and *Acacia melanoxylon* to 6 m tall, with scattered taller *Eucalyptus nobilis* and *Acacia melanoxylon* (overstorey class 4), sampled only on one steep, rocky scree slope below a cliff in the far east of the area. The moderately dense ground cover is composed mainly of *Australina pusilla, Polystichum proliferum, Smilax australis* and *Urtica incisa.* Remarkably, this steep, stony area along with much of the surrounding area on less extreme slopes, was extensively ringbarked about fifty years previously. This past disturbance has undoubtedly had some effect on present understorey composition, although broadly similar understorey occurs on apparently undisturbed lower slopes and along creeks in deeply incised parts of Jemmys Creek. Scattered emergent individuals of *Casuarina cunninghamiana* occur along the creek in this latter area. Moist forest is of limited distribution in the Coolah Tops area, confined to sheltered lower slopes in less accessible areas.

Floristic group 2. Riparian forest

2.1 *Pittosporum undulatum–Doodia aspera*
Plot WAR003; R=67

Open forest sampled only as a narrow riparian strip along a branch of Jemmys Creek at low altitude, comprising a mosaic of small tree and shrub thickets up to 12 m tall (especially *Angophora floribunda, Pittosporum undulatum, Acacia melanoxylon* and *Rapanea howittiana*) mixed with patches of dense herbaceous ground cover. The most abundant ground cover species are the ferns *Doodia aspera, Adiantum aethiopicum Calochlaena dubia* and *Hypolepis glandulifera,* herbs *Australina pusilla* and *Hydrocotyle laxiflora* and twiner *Desmodium varians.* This floristic community represents the moister end of the gradient for overstorey community 3.1, dominated by *Eucalyptus bridgesiana* and *Eucalyptus laevopinea.* A more extensive area of floristically similar vegetation, but with a denser small tree stratum, occurs on sheltered slopes in the headwaters of Branch Creek.

2.2 *Casuarina cunninghamii–Hydrocotyle peduncularis*
Plot WAR028; R=77

Open forest clearly dominated by *Casuarina cunninghamiana* (overstorey class 3.3) with occasional *Eucalyptus laevopinea* and *Eucalyptus nobilis,* especially near the edge of the stand, and a subcanopy of *Angophora floribunda.* Understorey is mainly a mosaic of a dense, low ground cover dominated by the herb *Hydrocotyle peduncularis,* interspersed with taller patches of the fern *Hypolepis glandulifera.* This community is floristically similar to WARf 2.1, but is along a larger, more open creek and has a higher proportion of species characteristic of aquatic and swampy habitats. In the survey area *Casuarina cunninghamiana* occurs fairly commonly as scattered trees along larger creeks below about 900 m altitude, but seldom forms distinct stands. The sample plot is representative of a narrow (up to 20 m wide) riparian strip extending for several hundred metres along one section of Cattle Creek, but no other similar stands were observed along other creeks nearby. Judging from remaining remnants, this community was previously widespread in surrounding private property.

2.3 *Acacia melanoxylon–Acaena novae-zelandiae*
Plots WAR017, WAR030; R=63-94

Open forest or woodland up to 28 m tall with a mixed shrubby and herbaceous understorey. The overstorey is variously dominated by *Eucalyptus nobilis* (overstorey class 4) or *Eucalyptus laevopinea* and *Angophora floribunda* (class 3.1). Main small trees and shrubs (up to 3 m tall) are *Acacia melanoxylon*, *Coprosma quadrifida* and *Lomatia arborescens*. The mostly dense ground cover is diverse, common species being *Acaena nova-zelandiae, Dichondra repens, Hydrocotyle peduncularis* and *Hypolepis glandulifera*. *Geranium retrorsum* and the vine *Smilax australis* may be locally common. This is the characteristic riparian vegetation along larger streams draining the slopes at moderate to high altitudes. Along more deeply dissected creeks at slightly lower altitudes (750–900 m), lower slopes support dense, tall shrub understorey clearly dominated by *Hymenanthera dentata*, with the thorny vine *Smilax australis* also abundant. Narrow riparian strips in these areas support scattered emergent eucalypts, *Angophora floribunda* and *Casuarina cunninghamiana* over an uneven low canopy including a number of rainforest elements such as *Rapanea howittiana*, *Pittosporum undulatum* and *Marsdenia rostrata*.

2.4 *Eucalyptus dalrympleana* ssp. *heptantha–Hydrocotyle peduncularis*
Plot WAR011; R=86

Woodland of *Eucalyptus dalrympleana* ssp. *heptantha* and *Eucalyptus stellulata* (overstorey class 6) with diverse understorey, occurring as narrow riparian strips along small, rocky creeks on the plateau. Shrub thickets dominated by *Leptospermum gregarium* are interspersed with patches of dense low ground cover variously dominated by *Acaena novae-zelandiae, Blechnum minus, Hydrocotyle peduncularis* or the exotic *Trifolium repens*. Aquatic species such as *Myriophyllum variifolium* and *Potamogeton tricarinatus* are locally abundant in larger pools in the creek. Overstorey community 6 is restricted to riparian sites along small creeks on the plateau and around swamp margins. It grades into community 5 (*Eucalyptus pauciflora*) upslope.

2.5 *Callistemon sieberi–Hydrocotyle peduncularis*
Plot BUN005; R=59

Woodland up to 25 m tall of scattered *Eucalyptus laevopinea* with a subcanopy to 12 m of individuals and small stands of *Callistemon sieberi*. Isolated shrubs of *Callistemon sieberi* and *Notelaea microcarpa* are interspersed with patches of herbaceous ground cover and extensive areas of bare rock and open water. The most common ground cover species are *Gratiola peruviana* and *Hydrocotyle peduncularis*. *Polystichum fallax* is locally abundant on steep, stony creek banks. This riparian community is similar to 2.4, but occurs where the proportion of outcropping rock is higher. It is the only habitat in the area for the rare epilithic fern *Asplenium trichomanes* subsp. *quadrivalens*. The combination of tree species (overstorey community 9) was recorded only along Rocky

Creek near the north-western boundary of the forest, but broadly similar vegetation is typical of riparian zones of rocky creek beds on the plateau.

Floristic group 3. Plateau grassy forest

3.1 ***Eucalyptus laevopinea–Pteridium esculentum***
Plot UL4.2; R=20

An area of several hectares in the former Jemmys Creek Flora Reserve, dominated by *Eucalyptus laevopinea* (overstorey community 1.1), with a very dense ground cover dominated by the ferns *Pteridium esculentum* and *Calochlaena dubia*. Because of the very dense structure of these ferns, floristic diversity is unusually low. Other patches locally dominated by these ferns occur scattered throughout the open forests of the plateau, but the total extent is not large.

3.2 ***Acacia dealbata–Poa sieberiana***
Plots OL3.3, RL3.3, RL4.3, UL2.3, UL3.3, WAR004, WAR013, WAR014; R=29-49, median=43.5

Open forest or woodland, 25–35 m tall (median 30 m), which is very widespread on the plateau, occurring in a wide range of habitats but mostly avoiding steep slopes, creeks and areas of impeded drainage. The overstorey is mostly community 5, usually clearly dominated by *Eucalyptus pauciflora*, with *Eucalyptus nobilis* as a frequent but less common associate. *Eucalyptus stellulata* is often present as occasional subcanopy trees, and is sometimes locally common. Occasionally the overstorey is community 1.1, *Eucalyptus laevopinea*. There is a sparse to moderately dense shrub stratum 1–4 m tall dominated by *Acacia dealbata* and a mostly dense grassy ground cover clearly dominated by *Poa sieberiana*. Other species are far less prominent, and include *Asperula conferta, Hydrocotyle laxiflora, Arthropodium* species B and *Glycine clandestina*. This is the single most widespread community associated with *Eucalyptus pauciflora* forests at the higher altitudes (1120–1200 m, median 1160 m). The other, similar very widespread plateau floristic community, 3.6, is mostly associated with *Eucalyptus laevopinea* (overstorey community 1.1) and occurs at slightly lower altitudes.

3.3 ***Acaena novae-zelandiae–Danthonia racemosa***
Plots WAR007, WAR008, WAR009; R=49-53

Fairly widespread in open forest on the plateau in the western half of the area, but not sampled elsewhere. Although there are many species in common with the widespread grassy understorey communities (3.2 and 3.6), this community is characterised by the relative lack of *Poa* spp. and dominance of the low herb *Acaena novae-zelandiae* and tufted grass *Danthonia racemosa*. It is associated with a range of plateau overstorey communities (Table 3). In plot WAR007, *Eucalyptus laevopinea* is co-dominant with *Eucalyptus bridgesiana* around the margin of a swampy depression. Although covering several hectares at the sample site, no stands of similar overstorey composition were observed elsewhere in the survey area, *Eucalyptus bridgesiana* mostly occurring with *Eucalyptus melliodora* on slopes at lower altitudes.

3.4 *Aceana novae-zelandiae*
Plot WAR006; R=51

This community is very similar to 3.3 and occurs in similar habitats. It differs primarily in the absence of *Danthonia racemosa.*

3.5 *Eucalyptus laevopinea–Hydrocotyle laxiflora-Pteridium esculentum*
Plots OL4.3, WAR019, WAR022; R=41–46

Open forest of *Eucalyptus laevopinea* (overstorey community 1.1) with a mixed herbaceous ground cover and virtually non-existent shrub stratum. Apart from *Hydrocotyle laxiflora,* frequent and common ground cover species include the fern *Pteridium esculentum,* thorny vine *Smilax australis,* twiner *Desmodium varians,* herb *Dichondra repens* and tussock grass *Poa labillardieri.*

3.6 *Poa labillardieri-Pteridium esculentum*
Plots OL2.3, RL2.3, UL1.3, WAR010, WAR021, BUN006, BUN007, BUN008; R=36–45, median=41

Grassy open forest or occasionally woodland 22-45 m tall (median height 28 m) with few shrubs and a usually dense ground cover clearly dominated by *Poa labillardieri. Pteridium esculentum* is also usually common and may locally form dense thickets. Other common species are *Hydrocotyle laxiflora, Acaena novae-zelandiae, Wahlenbergia stricta, Microlaena stipoides, Dichondra repens, Gnaphalium gymnocephalum, Danthonia* spp., *Viola betonicifolia, Desmodium varians, Dichelachne* spp. and *Glycine clandestina.* This is one of the most widespread floristic communities on the plateau and occurs at slightly lower altitudes (1050–1140 m, median 1110 m) than the other main plateau floristic community, 3.2. It is usually associated with overstorey community 1.1, where *Eucalyptus laevopinea* is usually clearly and often solely dominant. *Eucalyptus nobilis* is the most frequent associate and may be locally dominant (overstorey community 4). At the 0.1 ha scale used for sample plots, most stands are dominated by one or other of these two overstorey species and stands in which the two species are co-dominant are rare. At a broader scale, *Eucalyptus nobilis* occurs scattered through many of the extensive stands of *Eucalyptus laevopinea.*

3.7 *Eucalyptus praecox–Acaena novae-zelandiae*
Plots WAR002, WAR031; R=47–63

This community is floristically similar to WARf 3.6, but with *Poa labillardieri* a minor component and *Acaena novae-zelandiae* relatively more common. It differs structurally in generally having sparser ground cover. It is of fairly restricted extent, occurring locally and sporadically on upper slopes, mainly around the south-eastern edge of the plateau. *Eucalyptus praecox* and *Eucalyptus laevopinea* are co-dominant in the overstorey (overstorey community 1.2).

3.8 *Eucalyptus laevopinea–Viola betonicifolia*
Plots BUN003, OL1.3, RL1.3, WAR012, WAR016; R=18–62, median=34

Open forest with mostly sparse ground cover and no shrub stratum, characterised by relative lack of grasses in the understorey. No single understorey species is clearly dominant. Frequent species include *Viola betonicifolia, Hydrocotyle laxiflora* and

Gnaphalium gymnocephalum. Overall floristically similar to other plateau communities, but it appears to be mainly associated with dense regrowth stands of mainly *Eucalyptus laevopinea* (overstorey community 1.1) where overstorey competition suppresses understorey development. This floristic community includes four understorey communities, and is predominantly characterised by the dense canopy cover of *Eucalyptus laevopinea* which, in the classification analysis, has tended to mask the contribution from the understorey species which have mostly low cover. Plots WAR012, WAR016 and RL1.3 belong to two of the most widespread understorey communities, charaterised respectively by relative abundance of *Acaena novae-zelandiae* (WAR012, WAR016) and *Microlaena stipoides* (RL1.3). Plot OL1.3 is one of two plots in understorey community 5, which has a relatively higher cover of *Danthonia racemosa* than other similar open forest communities. Plot BUN003 is uniquely understorey community 17. This plot has a virtually non-existent understorey with no dominant species. Even though the understorey species are shared with other grassy forest communities, it is classified separately by the understorey classification because of the very low overall cover.

Floristic group 4. Dry slopes forest and woodland

4.1 *Eucalyptus melliodora–Microlaena stipoides*

Plots WAR026, WAR027, WAR032; R=55–67, median=62

Woodland to open forest 20–25 m tall of *Eucalyptus melliodora* and *Eucalyptus laevopinea* (overstorey community 2). These two overstorey species are usually co-dominant, although *Eucalyptus melliodora* may be locally more abundant and plot WAR032 samples a small area where this species is locally solely dominant and *Eucalyptus laevopinea* is absent. *Eucalyptus bridgesiana* occurs as occasional individuals and is locally common in patches, especially at lower altitudes (e.g. plot WAR026), and overstorey community 2 intergrades extensively with 3.1 (*Eucalyptus laevopinea–Eucalyptus bridgesiana*). Although not recorded during the present survey, *Eucalyptus moluccana* is reported from the steeper slopes (Forestry Commission of NSW 1982) and may be associated with this floristic community, although the presence of this species requires confirmation. There is typically a subcanopy of *Angophora floribunda* or *Allocasuarina torulosa*, or commonly both species. The understorey comprises a scattered to moderately dense shrub stratum to 2 m tall, main shrub species being *Olearia elliptica*, *Cassinia quinquefaria* and *Bursaria spinosa*. The ground stratum is of mixed composition with no clear dominants, but common species include the grasses *Microlaena stipoides* and *Echinopogon ovatus*, the herbs *Acaena novae-zelandiae* and *Dichondra repens* and the twiner *Desmodium varians*. This community is extensive over slopes below the plateau, especially lower slopes on deeper soils in the eastern part of the survey area, mainly below 800 m altitude but extending to the plateau at about 1000 m in a few places. It shares many species with plateau communities, although the relative abundances differ considerably, and includes two understorey communities (Table 2). Plots WAR026 and WAR027 belong to understorey community 8, which has *Microlaena stipoides* and *Echinopogon ovatus* as the most common constituents. WAR032 has more in common with grassy plateau communities and belongs to the widespread understorey community 6, in which *Acaena novae–zelandiae* is relatively more common.

4.2 *Eucalyptus melliodora–Cassinia quinquefaria*
Plots WAR029, WAR033; R=54–62

Open forest of *Eucalyptus laevopinea*, *Eucalyptus bridgesiana* and *Eucalyptus melliodora* in varying proportions (overstorey communities 1.1 and 3.1), with a moderate to very dense shrub understorey 1–3 m tall and sparse ground cover. *Cassinia quinquefaria* is the dominant shrub species, but *Olearia elliptica* is usually present and may be locally dominant. Common ground cover and low shrub species include *Danthonia racemosa*, *Glycine clandestina* and *Swainsonia galegifolia*. This community is very widespread on the steep and usually rocky slopes of the southern and eastern escarpments of the area (below 800 m altitude) and could be regarded as the characteristic community of those habitats.

4.3 *Allocasuarina torulosa–Olearia elliptica*
Plot WAR001; R=65

Open forest characterised by a subcanopy of *Allocasuarina torulosa* and a sparse to dense shrub stratum of *Olearia elliptica* 1–2 m tall. This community is very similar to 4.2 and represents areas of local dominance of *Olearia elliptica.*

4.4 *Eucalyptus nortonii–Bothriochloa macra*
Plot WAR015; R=65

This community was recorded only as a small, heavily browsed area at low altitude on a dry slope in Norfolk Island Creek valley, at the western boundary of the forest adjacent to cleared grazing land. The overstorey is a low open forest or woodland of *Eucalyptus nortonii* (overstorey community 8). This overstorey community is of restricted extent in the area, occurring mostly below and sometimes immediately above the cliff line on the northern and western boundary. It is much more extensive in adjacent private property. Plot WAR015 is representative of a small area mapped as Forest Type 103. The understorey is unusual in that *Bothriochloa macra*, absent from plateau forests, is the single most abundant grass species. This native grass is apparently tolerant of heavy grazing and at the time of survey, formed a low turf at this site.

4.5 *Eucalyptus nortonii–Cassinia quinquefaria*
Plot BUN004; R=40

Low woodland of *Eucalyptus nortonii* with a dense shub stratum of *Cassinia quinquefaria*. Ground cover sparse, but of similar composition to that of grassy plateau forests. This community is restricted to slopes in the north-west of the area.

4.6 *Cassinia quinquefaria–Bothriochloa macra*
Plot BUN002; R=56

This is a mosaic of shrub thickets up to 4 m tall with low turf and bare rock, and scattered emergents of *Eucalyptus nortonii* and *Angophora floribunda* up to 15 m tall (overstorey community 3.2). Shrub layer mainly *Cassinia quinquefaria*, *Acacia neriifolia* and *Olearia elliptica*. The low, heavily browsed turf is dominated by *Danthonia laevis* and *Bothriochloa macra*. This plot is representative of several small patches on the plateau along the cliff top on the northern boundary of the study area. The skeletal soil over extensive rock slabs prevents establishment of denser tree growth.

Table 4. Plant species of conservation significance at Coolah Tops

Species	Significance	Distribution and habitat at Coolah Tops
Asplenium trichomanes subsp. *quadrivalens*	Local and sporadic in NSW, but cosmopolitan in temperate regions.	Small populations epilithic in sheltered microsites near waterfalls.
Discaria pubescens	Nationally rare, 3RCa, but widespread in NSW	Widespread in plateau grassy forest, but uncommon and sporadic and often more abundant near creeks. Largest single stand about 30 mature plants.
Macrozamia concinna (D.L. Jones ined.)	Nationally rare with restricted distribution, mainly occurring in the Nundle area	Scattered on rocky slopes in dry slopes forest in the far east of the area.
Teucrium species D	Restricted distribution, otherwise only in Tamworth district.	A single small population of less than 30 plants, on a steep, rocky slope near the western boundary of the study area.

Floristic group 5. Plateau swamp

5.1 *Leptospermum polygalifolium–Hydrocotyle peduncularis*
Plot WAR018; R=34

A mosaic of shrub thickets of *Leptospermum polygalifolium* with dense low herbfield dominated by *Hydrocotyle peduncularis*, and scattered emergents of *Eucalyptus dalrympleana* ssp. *heptantha*. This is a variant of 5.2 with similar composition of herbaceous vegetation but with the shrub stratum dominated by *Leptospermum polygalifolium* rather than *Leptospermum gregarium*.

5.2 *Leptospermum gregarium–Hydrocotyle peduncularis*
Plots BUN001, WAR005; R=22-34

This is typically a mosaic of very dense shrub thickets up to 3 m tall interspersed with dense low herbfields and turf, at a scale of tens of square metres to tenths of a hectare. The dominant shrub species are *Leptospermum gregarium* and *Hakea microcarpa*. Abundant ground cover herbs are *Eleocharis dietrichiana, Myriophyllum pedunculatum, Gonocarpus micranthus, Haloragis heterophylla, Hydrocotyle peduncularis, Isotoma fluviatilis* subsp. *borealis, Cyperus sphaeroideus, Hypericum japonicum* and *Schoenus apogon*. In most areas there are only isolated emergent eucalypts (mostly *Eucalyptus dalrympleana* subsp. *heptantha* or *Eucalyptus stellulata*), but a higher tree density occurs on hummocks and around swamp margins (overstorey community 6). This is the characteristic community of impeded drainage depressions in headwaters of minor creeks on the plateau. These areas suffer regular localised soil disturbance from activities of feral pigs, reflected in the occurrence of several exotic species such as *Juncus bufonius*. Where disturbance by pigs or cattle grazing is intensive, weeds such as *Trifolium repens* may become locally dominant. The very extensive swamp along

Norfolk Creek has a high proportion of naturalised species, but is otherwise similar to other swamp areas, and was not sampled.

Species of conservation significance

Only four of the species recorded during the survey are considered to be of conservation significance (Table 4). Only one of these (*Discaria pubescens*) is listed as nationally rare or threatened, coded 3RCa by Briggs and Leigh (1995). It is a very widespread but sporadic shrub which is considered adequately reserved, occurring in at least ten National Parks or Nature Reserves outside Coolah Tops. A further species, *Macrozamia concinna* (D.L. Jones ined.) is considered of national significance but has not been assigned a conservation code (D.L. Jones, pers. comm.). *Teucrium* species D has a restricted distribution, mainly in the Tamworth area, and also could be considered of national significance.

In addition to survey results, a search for records of rare plants was made of the January 1994 version of the ROTAP database (NSW National Parks and Wildlife Service) for the rectangle bounded by 31°41'–31°53' and 149°55'–150°17'E, which includes Coolah Tops and surrounding plains. This database contained only one record from Coolah Tops, of *Callistemon shiressii* from Norfolk Falls. This is almost certainly the result of misidentification of *Callistemon sieberi*, as it is not supported by a specimen and *C. shiressii* is otherwise known only from a restricted area between Colo River and Howes Valley in central coastal NSW, growing on sandstone. Two additional species are recorded in this database from private property on the plains from within the defined rectangle, but not from Coolah Tops. *Bothriochloa biloba* (3V) is represented by two records and may occur in grassy woodland at the base of the slopes. *Thesium australe* (3VCi+) is represented by a single record from near Blackville, in the valley to the north of Coolah Tops. Griffith (1992) lists an additional record from Cassilis. This species is almost invariably associated with grassy understorey dominated by *Themeda australis*. No community of this type was recorded during the survey and there is only a low probability that *Thesium australe* would occur in the Coolah Tops area.

Floristic patterns in relation to logging, grazing and environmental factors

The two-dimensional ordination from CCA (Fig. 5), is plotted with ellipses representing twice the standard deviation around centroids for logged and unlogged plots, and arrows representing several environmental variables as described above under methods. The ellipses are plotted as a guide only, as the data are not multivariate normal and the shape of the ellipse will be exaggerated by outliers. The relatively longer arrows for grazing history and altitude suggests that these variables contribute to floristic variation to a greater extent than does logging history. Overstorey type, logging history and degree of topographic exposure contribute to a lesser extent, and the latter two are correlated to some extent, so that floristic variation in relation to logging history may also, or alternatively, be related to topographic exposure. When floristic data are ordered along the logging history vector, species which tend to be most strongly associated with unlogged plots are *Pterostylis coccina*, *Leucopogon lanceolatus, Dianella longifolia, Hypericum gramineum* and *Gonocarpus humilis.* Species which are associated with the logged end of the floristic gradient, especially recently logged plots, include *Urtica incisa, Pteridium esculentum, Echinopogon ovatus, Stellaria pungens, Stipa rudis* subsp. *nervosa* and *Cynoglossum australe,* and the naturalised alien herbs *Sonchus oleraceus, Conyza albida* and *Taraxacum officionale.*

Logged plots have a floristic richness which is very similar to but slightly lower than unlogged plots, overall. Median richness for unlogged plots which sample areas potentially able to be logged (n=14) is 44 species per 0.1 ha plot. For recently (<10 yrs) logged plots (n=6) it is 41 and for older (20–40 yrs) logged plots (n=9) it is 42 species per plot. There were no statistically significant differences among these results ($p > 0.5$, Kruskal-Wallis Test). A total of 127 species was recorded from logged plots and 145 from unlogged but loggable plots. 102 species were recorded in both logged and unlogged but loggable plots. A total of forty-three species was recorded from unlogged plots which could potentially be logged, but not from logged plots.

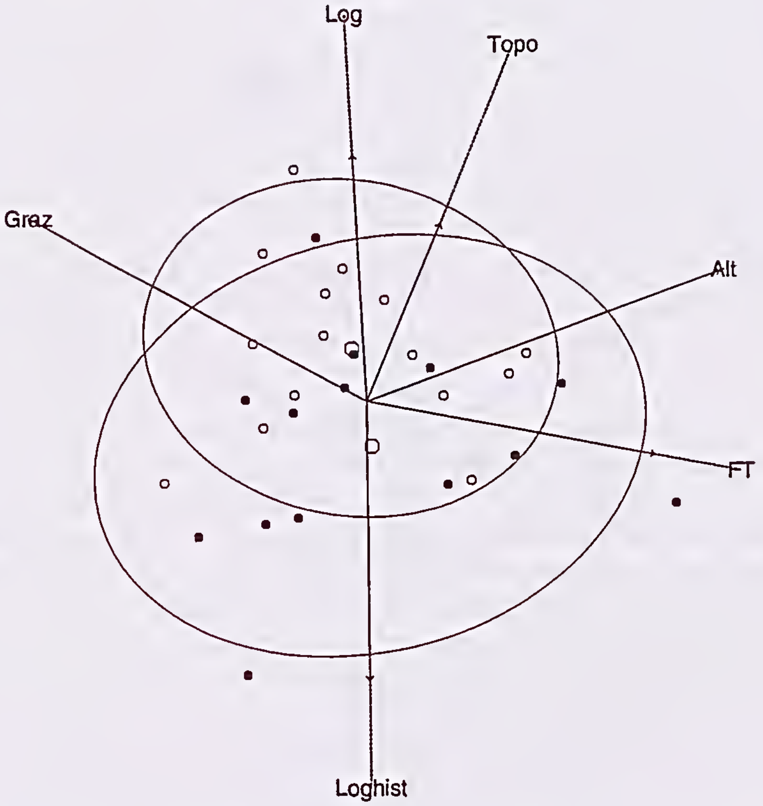

Fig. 5. CCA ordination of logged and loggable plots with logging category superimposed. Filled symbols represent logged plots and open symbols represent unlogged plots. Ellipses are twice standard deviation from the centroid for each logging group. Environmental variables are displayed as arrows: Log = time since logging (recent to unlogged), Loghist = logged (1) or unlogged (0), Topo = topographic position (exposed to sheltered), Alt = altitude (low to high), Graz = grazing (0 ungrazed, 1 grazed), FT = overstorey community group number.

Although it is not possible to accurately assess grazing history in the field on an individual plot basis, State Forests' management records (R. Irvine, District Forester, Dubbo, pers. comm.) indicate that the central area of the forest has been subject to a far lower intensity of grazing by domestic stock than elsewhere. The CCA ordination diagram with ellipses of twice standard deviation plotted around centroids for each grazing category (Fig. 6) shows a strong tendency for separation of lightly grazed from more heavily grazed plots, with relatively little overlap. Ordering of species along the grazing category vector suggests that species which are associated with less heavily grazed plots include the shrubs *Acacia dealbata* and *Lomatia arborescens*, twiners *Glycine clandestina* and *Hardenbergia violacea*, abundant tussock grass *Poa sieberiana*, forb *Gonocarpus humilis* and orchid *Pterostylis coccina*. Species which occur in more heavily grazed plots include forbs *Acaena novae-zelandiae*, *Gnaphalium gymnocephalum* and *Urtica incisa*, grasses *Danthonia laevis*, *Microlaena stipoides*, *Stipa rudis* and *Echinopogon ovatus* and graminoid *Lomandra filiformis*. However, the CCA plot also suggests a strong negative interaction between grazing and altitude, and this is supported by the negative correlation between these two factors (Spearman rank correlation

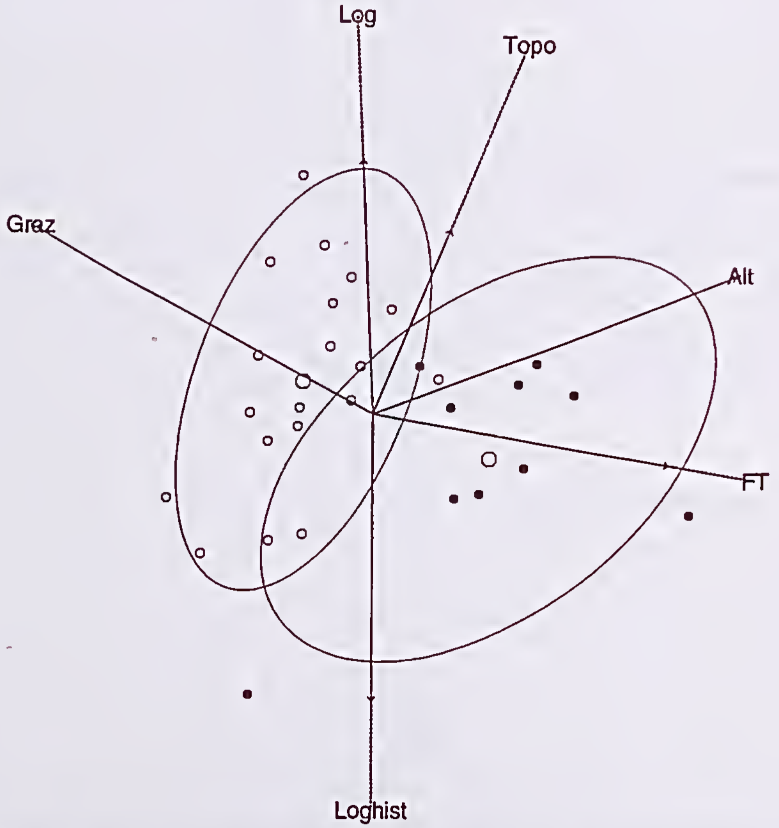

Fig. 6. CCA ordination of logged and loggable plots with grazing history superimposed. Filled symbols represent 'ungrazed' plots and open symbols represent grazed plots. Ellipses are twice standard deviation from the centroid for each grazing group. Environmental variables are displayed as arrows and defined as described for Fig. 5.

co-efficient = -0.61, p=0.0005). The more heavily grazed areas are those at slightly lower altitudes on the plateau. Thus, it is possible that the fairly strong floristic gradient apparently associated with grazing history may actually be an altitudinal gradient.

Discussion

Floristics and conservation of communities

Considered in isolation, the vegetation of the area is remarkably uniform, of low floristic diversity, supports very few significant vascular plant species and appears to have low intrinsic botanical conservation value. However, considered in a broader context, the area does have several important features of conservation and botanical significance. Geographically, the area represents a westerly extension of the northern tablelands intruding into the western slopes and forms a substantial part of an isolated basaltic plateau in a generally lower-altitude and largely cleared landscape. The combination of a discrete geographical unit within an otherwise largely cleared landscape gives the area an inherent general conservation significance, recognised in the forest Management Plan (Forestry Commission of NSW 1982). Botanically, the area clearly has strong floristic similarities to the northern tablelands to the north-east, but also has several unusual features. The extensive and structurally very well-developed *Eucalyptus pauciflora* forests, including the tallest recorded individuals of this species, are well-recognised (Forestry Commission of NSW 1982). The very extensive occurrence of both *Eucalyptus laevopinea* and *Eucalyptus nobilis*, the latter probably at its western limit of distribution, is also of significance. The other important feature is the absence of several eucalypts which are widespread and abundant elsewhere on the northern tablelands in similar habitats, notably *Eucalyptus campanulata* and *Eucalyptus obliqua*.

The assessments of Benson (1989) and Hager and Benson (1994) are used as an indication of conservation status of overstorey communities. Due to recent substantial increases in the National Park estate, especially in coastal and tablelands areas, some communities occurring in former State Forests would now be assessed as less threatened, although the status of communities which occur predominantly on private lands will not have changed significantly. The most extensive overstorey community in the area, 1.1 *Eucalyptus laevopinea*, is regarded as inadequately reserved generally, and poorly reserved in the southern part of the northern tablelands. Stands in which *Eucalyptus nobilis* is clearly dominant (overstorey community 4) are not recognised as a separate community, but are probably related to the poorly reserved Hager and Benson EF373 *Eucalyptus laevopinea–Eucalyptus nobilis*. Stands in which *Eucalyptus laevopinea* is co-dominant with *Eucalyptus praecox* (overstorey community 1.2) do not have a clear Benson equivalent, but could perhaps be regarded as a geographical variant of the related *Eucalyptus mannifera* ssp. *elliptica*, assessed as vulnerable. In any case, these stands are potentially of conservation significance.

Communities containing *Eucalyptus pauciflora*, *Eucalyptus stellulata* and/or *Eucalyptus dalrympleana* as dominants are assessed in the earlier of the two reports (Benson 1989) as not threatened, but inadequately reserved. Particular note is made of the inadequacy of reservation of *Eucalyptus pauciflora* at Coolah Tops. For the southern zone of the northern tablelands, Hager and Benson assess the equivalent associations as being adequately conserved, with at least ten and probably 25 per cent of the total area reserved (probably largely a result of extensive areas included in Barrington Tops NP).

The overstorey communities dominated by, or containing, species of boxes (2, 3.1, 3.2 and 8) have no clear Benson equivalent and must be regarded as being of significance. Communities 2 and 3.1 are most similar to the *Eucalyptus melliodora-Eucalyptus bridgesiana* association, which is assessed as poorly reserved and vulnerable. Communities 3.2 and 8, containing *Eucalyptus nortonii*, appear to have no equivalent association. In the study area, these communities occur mainly at lower altitudes adjacent to private property, much of the latter having been cleared. They are probably representative of some of the area now cleared (especially the steeper slopes), and could reasonably be regarded as remnants of previously relatively widespread communities in the surrounding foothills. However, there may have been substantial differences in understorey composition between the occurrences on Crown Land and those which previously existed in the surrounding private property. The Crown Land boundary invariably coincides with abrupt transitions in slope, with the steeper, rocky slopes with dense shrub understorey of *Cassinia quinquefaria* and *Olearia elliptica* in Crown tenure contrasting with the gentler slopes of adjacent private property. The understorey in the private property is mostly heavily grazed, dominated by exotics and difficult to relate to what would have been present prior to settlement. McRae & Cooper (1985) describe remnants on the nearby basalt plains (to the immediate south of the present survey area) as being woodlands of *Eucalyptus albens–Eucalyptus moluccana*, *Eucalyptus melliodora* and *Brachychiton populneus*. *Eucalyptus melliodora* is scattered at lower altitudes in the study area, but is a canopy dominant only in very limited areas close to the boundary with private property. Although *Eucalyptus moluccana* is recorded for the area in the management plan (Forestry Commission of NSW 1982), the original source of the record is unknown and this species was not recorded during recent survey.

Impact of past logging

Although both logged and unlogged stands were sampled, it was difficult to assess past logging impact, mainly because there are no detailed pre-logging data available, and substantial differences may exist between previously logged and unlogged areas irrespective of logging history. Present differences in vegetation may be related more to site factors other than logging history. However, survey data do provide an indication of possible logging impact in the context of spatial variability in vegetation of unlogged sites. As shown by the ordination diagram of Fig. 5, there does appear to be a weak impact of logging on floristic composition. It is possible that the observed pattern is related to site factors other than logging. For example, logging may have tended to occur in particular vegetation types, for productivity or other reasons, resulting in the observed apparent effect being an artefact of the distribution of logging treatment. Stands dominated by *Eucalyptus laevopinea* were more likely to have been previously logged than those dominated by *Eucalyptus pauciflora*, due to the higher commercial value of the former species. Degree of topographic exposure appears to be the variable most strongly correlated with logging (Fig. 5). Thus, the observed pattern of floristic composition in relation to logging may partly be due to topographic variation, with past logging avoiding more sheltered sites.

Examination of correlations between ordination scores and abundance of individual species gives some indication of which species potentially contribute most to observed differences in composition, but unfortunately provides only weak evidence of logging impact in terms of individual species, because logging categories are not clearly separated on the ordination diagram, and correlations with an individual species are more likely to be due to chance than those with a suite of species. It is also not possible to evaluate logging impact on the large proportion of species which occurred at low frequency in survey plots. More intensive survey would partly assist, but for most species, detailed and specifically-directed monitoring studies would be required to satisfactorily examine this issue. Using data from this survey, only five of the species which occurred at frequency ≥5 were significantly more frequent in unlogged plots. These were the native herbs *Dichelachne crinita*, *Hypericum gramineum*, *Pterostylis coccina* and *Picris angustifolia*, and the tree *Eucalyptus pauciflora*. The latter is most likely due to less likelihood of logging in forests containing this species, which is of low commercial value. *Hypericum gramineum* and *Pterostylis coccina* were also indicated as associated with unlogged plots by the ordination results. Species recorded more frequently in logged plots were *Cynoglossum australe*, *Echinopogon ovatus*, *Eucalyptus laevopinea* and *Pteridium esculentum*. As mentioned above, in the case of *Eucalyptus laevopinea* this is because forests containing that species are favoured for logging. The remaining three species are also indicated as favouring logged plots from the ordination results.

Following logging disturbance, vegetation may be expected to undergo successional change to some extent, at least in the most heavily affected patches. Ordination patterns suggest that this occurs to only a limited extent, probably because the majority of species present are either resilient to logging damage or quickly recolonize immediately after logging. For example, the most abundant understorey species in grassy forests, *Poa sieberiana* and *Poa labillardieri*, appear resilient to physical damage and recover quickly unless tussocks are completely uprooted. Unless there is severe soil disturbance, the species which were previously present quickly recover. The patchy nature of post-logging disturbance, whereby a substantial or major proportion of any 0.1 ha plot remains relatively undisturbed, results in any successional changes being confined to relatively small patches in the general logged area and contributes to overall lack of clear evidence of successional trends. Any changes which do occur are most pronounced in a few highly disturbed patches along roadsides, on snig tracks and on log dumps. Observations suggest that notable colonizing species are the naturalised herb *Conyza albida* and the native herbs *Cynoglossum australe*, *Pteridium esculentum* and *Acaena novae-zelandiae*. These species are all present in unlogged and older logged plots, but at reduced abundance. *C. albida* and *C. australe* probably colonize patches of disturbed soil from seed, while *P. esculentum* and *A. novae-zelandiae* proliferate vegetatively from rhizomes in areas where they previously existed. These species become less abundant over time, the naturalised species in particular decreasing to pre-logging levels within 10 years, while the native species tend to be more persistent.

Grazing and feral animals

The study area was extensively grazed by domestic cattle and sheep, at least immediately prior to recent dedication as a National Park. Grazing obviously has the potential to alter floristic composition by reducing the abundance of, or eliminating, preferred forage species. The extent to which this has occurred in the study area, if at all, is unknown. Low intensity grazing impact in forests is generally poorly known. Grazing may have a greater impact on floristic composition than does logging, and this warrants further investigation. However, it cannot be unequivocally stated that the observed relatively strong differences between the floristic composition of grazed and 'ungrazed' plots is due to grazing impact, since the plots are not interspersed and it is equally likely that floristic differences may actually be due to an altitudinal gradient, or interactions between altitude and grazing history. Due to the correlation between them, it is not possible to distinguish the effects of these factors from the data. For some species, there appears to be no logical reason, based on the little that is known of their ecology, for the observed differences to be due to grazing history, and altitude is the more likely explanation. Notable examples are *Poa sieberiana* in 'ungrazed' plots, and the soft grasses *Microlaena stipoides*, *Echinopogon ovatus* and *Danthonia laevis* associated with grazed plots when they might be expected to be preferentially browsed and be disadvantaged by higher grazing pressure. Other differences are perhaps more readily explained in terms of grazing history, notably the less palatable *Lomandra filiformis* favouring grazed plots, and the seasonal geophyte *Pterostylis coccina* being associated with 'ungrazed' plots.

Considerable soil disturbance caused by the foraging activities of feral pigs was observed during the survey, mainly in swampy heath and sedgelands. As this activity is concentrated in certain habitats, it is a potential threat to populations of species which are intolerant of such regular disturbance. Several herds of feral goats were observed during survey. Their activities are concentrated in rocky areas near cliffs. Much of the vegetation in these areas was heavily browsed at the time of survey, but whether goats or native wallaroos (also abundant) were mostly responsible was not clear. In any case, goats must be considered a potential threat to species which are restricted to rocky sites.

Weeds

Weed species (naturalised exotics) form a relatively small proportion (about 10 per cent) of the overall flora of the area. Most occur infrequently and are a minor component of the vegetation generally, although some species are very widespread. *Cirsium vulgare* and *Hypochoeris radicata* each occur in over thirty plots (over 60 per cent of the sample). These species often occur in relatively undisturbed forests. Their abundance in the study area may have been increased by both grazing and logging, although survey data suggest that neither species is more frequently associated with either logged or more heavily grazed plots. Weeds which do increase in abundance following logging decrease to pre-logging levels within 10 years. Although widespread, weeds are not sufficiently abundant at present to seriously threaten the integrity of native vegetation in the area in the short term. Clover, *Trifolium repens*, is locally common in previously heavily-grazed areas near swamps and may constitute a threat to herb communities in local areas. Several species of declared noxious weeds, such as *Hypericum perforatum* and *Chondrilla juncea*, while currently rare or infrequent, have the potential to increase in abundance and possibly pose a flora conservation threat. Blackberry, *Rubus ulmifolius/R. discolor* complex, is infrequent but locally common, particularly in riparian sites near private property boundaries. Local infestations have been previously controlled using herbicides, but it may pose a future threat to flora conservation in the absence of such control. Broom, *Cytisus scoparius*, has not been recorded from Coolah Tops, but poses a very serious flora conservation threat in broadly similar habitats on Barrington Tops. Any outbreak of this species should be immediately controlled.

Management issues

The change in tenure from State Forest to National Park has secured the reservation of a large area of *Eucalyptus laevopinea*-dominated grassy forest, which otherwise would have been subject to continued selective logging. This is likely to have some flora conservation advantage, although the impacts of past logging are not clear. The other communities of conservation significance would have remained unaffected by current logging practices, although past exploitation for fencing timber by adjacent landholders probably would have continued at a low level. The changes in tenure formalise the reservation of some of these communities (the proportion not still held under lease tenure) but otherwise have little effect on flora conservation status.

Ferals pigs and goats have the potential to reduce flora conservation values. If possible, they should be eliminated from the area, or at least their numbers should be maintained at low levels by appropriate control measures. Grazing may have greater impact on floristic composition than other previous disturbance such as logging. Domestic grazing should be excluded from the area. Weeds are not considered to be a serious threat in the short term, and to some extent their spread will be controlled by controlling grazing and feral animals which are likely to be important vectors. Two species which currently occur as small localised populations but will need specific control if populations increase are Blackberry and St. John's Wort, *Hypericum perforatum*. The former has been controlled previously by herbicide and may spread in future if left unchecked. The latter occurs mainly on private land but small populations occur in the study area adjacent to the private property boundary and isolated plants occur sporadically elsewhere in the forest, mostly not far from private property.

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Appendix 1

Species are listed alphabetically by family within classes, and nomenclature follows the National Herbarium of New South Wales. Frequency of occurrence is shown for each species, as a percentage of the total number of plots in each broad floristic group (indicated beneath the heading). There is an overall total of 50 plots. Floristic groups are derived from classification of all species as indicated below and described in the text.

.	species not recorded in that group.
+	species recorded in that group but not in a survey plot
*	naturalised species
H	specimen from area retained at State Forests herbarium, Research Division, West Pennant Hills
M	recorded in Management Plan but not during survey, details unknown

Floristic group: (refer to text)

MF=Moist Forest (group 1)

RpF=Riparian Forest and Woodland (group 2)

PGF=Plateau Grassy Forest (group 3)

DW=Dry slopes forest and woodland (group 4)

Sw=Swamp and Sedgeland (group 5)

Logging category:

L1=logged <10yr

UL1=unlogged,loggable

L2=logged >20yr

UL2=unlogged,unloggable (steep, non-commercial or non-forest)

			Floristic Group					**Logging Category**			
		Tot. freq.	**MF (1)**	**RpF (6)**	**PGF (31)**	**DW (9)**	**Sw (3)**	**L1 (6)**	**L2 (9)**	**UL1 (14)**	**UL2 (21)**
Class FILICOPSIDA											
ADIANTACEAE											
Adiantum aethiopicum		10	.	1.00	0.03	0.33	.	.	.	0.07	0.43
Adiantum formosum		1	.	0.17	.	.	.	.	.	.	0.05
Cheilanthes austrotenuifolia	M	+									
Cheilanthes distans		4	.	.	.	0.44	.	.	.	.	0.19
Cheilanthes sieberi subsp. *sieberi*		3	.	0.17	.	0.22	.	.	.	.	0.14
ASPLENIACEAE											
Asplenium flabellifolium		5	1.00	0.33	0.03	0.11	.	.	.	0.07	0.19
Asplenium trichomanes subsp. *quadrivalens*	H	1	.	0.17	.	.	.	.	.	.	0.05
ATHYRIACEAE											
Diplazium australe	M	+									
BLECHNACEAE											
Blechnum minus	H	4	.	0.67	.	.	.	.	.	.	0.19
Blechnum nudum		1	.	0.17	.	.	.	.	.	.	0.05
Doodia aspera		7	1.00	0.33	0.10	0.11	.	0.17	0.11	0.07	0.19
Doodia caudata var. *caudata*	H	3	.	0.50	.	.	.	.	.	.	0.14

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
DENNSTAEDTIACEAE											
Histiopteris incisa		+	+	.	.	.	.	.	.	.	+
Hypolepis glandulifera		4	.	0.67	.	.	.	.	.	.	0.19
Pteridium esculentum		31	1.00	0.67	0.77	0.11	0.33	1.00	0.89	0.64	0.38
DICKSONIACEAE											
Calochlaena dubia		3	.	0.17	0.06	.	.	0.17	.	0.07	0.05
DRYOPTERIDACEAE											
Polystichum fallax	H	5	.	0.67	0.03	.	.	.	.	0.07	0.19
Polystichum proliferum	H	4	1.00	0.17	0.06	.	.	0.17	0.11	.	0.10
OPHIOGLOSSACEAE											
Botrychium australe		1	.	.	.	0.11	.	.	.	.	0.05
Ophioglossum lusitanicum	H	1	.	0.17	.	.	.	.	.	.	0.05
PTERIDACEAE											
Pteris tremula		4	.	0.50	.	0.11	.	.	.	.	0.19
SINOPTERIDACEAE											
Pellaea falcata var. *falcata*		9	1.00	0.50	0.03	0.44	.	.	.	0.07	0.38
Class CONIFEROPSIDA											
CUPRESSACEAE											
Callitris endlicheri		+	.	.	.	.	+	.	.	.	+
Class CYCADOPSIDA											
ZAMIACEAE											
Macrozamia concinna (D.L. Jones ined.)	H	2	.	.	.	0.22	.	.	.	.	0.10
Class MAGNOLIOPSIDA–MAGNOLIIDAE											
ACANTHACEAE											
Brunoniella australis		2	.	.	.	0.22	.	.	.	.	0.10
APIACEAE											
**Berula erecta*	H	4	.	0.67	.	.	.	.	.	.	0.19
Daucus glochidiatus		9	.	0.33	0.13	0.33	.	.	0.11	0.21	0.24
Hydrocotyle laxifolia		45	1.00	0.83	1.00	0.89	.	1.00	1.00	1.00	0.76
Hydrocotyle peduncularis		15	1.00	1.00	0.16	.	1.00	0.17	0.11	0.21	0.48
Hydrocotyle tripartita		3	.	0.33	.	.	0.33	.	.	.	0.14
Lilaeopsis polyantha	H	3	.	0.50	.	.	.	.	.	.	0.14
Oreomyrrhis eriopoda		3	.	.	0.10	.	.	.	.	0.21	.
Trachymene anisocarpa	M	+									

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
ARALIACEAE											
Polyscias sambucifolia		4	.	.	0.13	.	.	.	0.22	0.14	.
ASCLEPIADACEAE											
Marsdenia rostrata		1	.	0.17	.	.	.	.	.	.	0.05
ASTERACEAE											
Ammobium alatum	H	+	.	+	.	.	.	+	.	.	.
**Bidens pilosa*		1	.	.	.	0.11	.	.	.	.	0.05
Brachycome dissectifolia	H	4	.	0.33	.	0.11	0.33	.	.	.	0.19
Brachycome microcarpa		27	.	.	0.81	0.22	.	0.83	0.56	0.93	0.19
Brachycome procumbens	M	+									
Cassinia compacta	H	5	.	0.17	0.10	0.11	.	0.33	.	0.07	0.10
Cassinia quinquefaria		12	.	0.17	0.06	1.00	.	.	0.11	.	0.52
**Chondrilla juncea*	H	+	.	+	.	.	.	+	.	.	.
**Cirsium vulgare*		35	.	1.00	0.74	0.67	.	0.83	0.56	0.79	0.67
**Conyza albida*	H	14	.	0.67	0.19	0.44	.	0.67	0.11	0.07	0.38
Craspedia variabilis	M	+									
Cymbonotus preissianus	H	2	.	.	0.03	0.11	.	0.17	.	.	0.05
Cymbonotus spp.		9	.	0.33	0.16	0.22	.	.	0.11	0.21	0.24
Gnaphalium gymnocephalum	H	35	.	0.83	0.74	0.44	1.00	0.83	0.89	0.57	0.67
Gnaphalium involucratum	H	6	.	0.33	0.03	0.33	.	.	0.11	.	0.24
**Hypochoeris radicata*		34	.	0.67	0.71	0.67	0.67	0.50	0.78	0.71	0.67
**Lactuca serriola*		5	.	0.17	0.10	0.11	.	.	.	0.21	0.10
Lagenifera stipitata		12	.	0.17	0.29	0.22	.	.	0.56	0.29	0.14
Microseris lanceolata	H	3	.	.	0.10	.	.	0.17	0.11	0.07	.
Olearia alpicola	H	5	.	0.33	0.10	.	.	.	0.11	0.14	0.10
Olearia chrysophylla	M	+									
Olearia elliptica		12	.	0.33	0.06	0.89	.	.	.	0.07	0.52
Picris angustifolia		26	.	0.83	0.39	1.00	.	0.17	0.22	0.57	0.71
Rhodanthe anthemoides	H	2	.	0.17	.	0.11	.	.	.	.	0.10
Senecio biserratus	H	4	.	0.33	0.03	0.11	.	.	.	0.07	0.14
Senecio diaschides	H	24	.	0.33	0.61	0.33	.	0.67	0.56	0.64	0.29
Senecio hispidulus var. *dissectus*	H	1	.	.	.	0.11	.	.	.	.	0.05
Senecio hispidulus var. *hispidulus*		1	.	.	.	0.11	.	.	.	.	0.05
Senecio lautus subsp. *dissectifolius*	H	4	.	0.17	0.03	0.22	.	.	.	0.07	0.14

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
Senecio linearifolius		2	.	0.17	0.03	.	.	0.17	.	.	0.05
**Senecio madagascariensis*		2	.	.	0.03	0.11	.	.	.	0.07	0.05
Senecio quadridentatus		6	.	0.17	.	0.56	.	.	.	.	0.29
Senecio sp. E (aff. *apargiaefolius*)		2	.	0.17	0.03	.	.	.	.	.	0.10
Sigesbeckia australiensis	H	7	.	0.17	.	0.67	.	.	.	.	0.33
**Sigesbeckia orientalis*		6	.	0.33	.	0.44	.	.	.	.	0.29
Solenogyne bellioides	H	1	.	.	.	0.11	.	.	.	.	0.05
Solenogyne gunnii	H	9	.	0.33	0.16	0.22	.	.	0.11	0.14	0.29
**Sonchus asper*		5	.	0.17	0.10	.	0.33	0.17	0.11	0.07	0.10
**Sonchus oleraceus*		10	.	0.17	0.29	.	.	0.50	0.22	0.29	0.05
**Taraxacum officinale*		13	.	0.50	0.19	0.44	.	0.67	0.11	0.07	0.33
Triptilodiscus pygmaeus	H	1	.	.	.	0.11	.	.	.	.	0.05
Vittadinia cuneata var. *hirsuta*	H	3	.	.	.	0.33	.	.	.	.	0.14
Vittadinia tenuissima	H	+	.	.	.	.	+	.	.	.	+
BIGNONIACEAE											
Pandorea pandorana		+	+	.	.	.	.	.	.	+	.
BORAGINACEAE											
Austrocynoglossum latifolium		3	.	0.17	0.03	0.11	.	.	.	0.07	0.10
Cynoglossum australe		20	.	0.33	0.52	0.22	.	1.00	0.78	0.21	0.19
BRASSICACEAE											
Cardamine paucijuga	H	5	1.00	0.17	0.10	.	.	0.17	.	0.14	0.10
Rorippa laciniata	M	+									
CAMPANULACEAE											
Wahlenbergia luteola	H	1	.	.	.	0.11	.	.	.	.	0.05
Wahlenbergia planiflora subsp. *planiflora*	H	2	.	.	0.06	.	.	.	.	0.14	.
Wahlenbergia stricta	H	37	.	0.67	0.90	0.56	.	1.00	1.00	0.86	0.48
Wahlenbergia spp.		3	.	.	.	0.33	.	.	.	.	0.14
CAPRIFOLIACEAE											
Sambucus gaudichaudiana		1	1.00	.	.	.	.	.	.	.	0.05
CARYOPHYLLACEAE											
**Cerastium fontanum* subsp. *vulgare*	H	2	.	0.17	.	0.11	.	.	.	.	0.10
Gypsophila tubulosa	H	2	.	.	.	0.22	.	.	.	.	0.10
**Paronychia brasiliana*	H	1	.	.	.	0.11	.	.	.	.	0.05

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
**Petrorhagia velutina*		3	.	.	.	0.33	.	.	.	.	0.14
**Polycarpon tetraphyllum*		4	.	.	0.03	0.33	.	0.17	.	.	0.14
Scleranthus biflorus		7	.	0.17	0.13	0.22	.	.	.	0.21	0.19
Stellaria angustifolia	H	4	.	0.33	.	.	0.67	.	.	.	0.19
**Stellaria media*		3	.	0.33	.	0.11	.	.	.	.	0.14
Stellaria pungens		15	.	0.33	0.42	.	.	0.50	0.56	0.36	0.10
CASUARINACEAE											
Allocasuarina torulosa		3	.	.	.	0.33	.	.	.	.	0.14
Casuarina cunninghamiana		1	.	0.17	.	.	.	.	.	.	0.05
CHENOPODIACEAE											
**Chenopodium album*		1	.	.	0.03	.	.	.	.	0.07	.
Chenopodium pumilio		1	.	.	0.03	.	.	.	0.11	.	.
Einadia nutans subsp. *nutans*	H	3	.	.	.	0.33	.	.	.	.	0.14
Einadia trigonos subsp. *leiocarpa*	H	2	.	0.17	.	0.11	.	.	.	.	0.10
CLUSIACEAE											
Hypericum gramineum		20	.	0.17	0.35	0.67	0.67	.	0.11	0.57	0.52
Hypericum japonicum		9	.	0.67	0.06	.	1.00	.	.	0.14	0.33
**Hypericum perforatum*		3	.	0.17	0.03	0.11	.	.	.	.	0.14
CONVOLVULACEAE											
Dichondra repens		41	.	0.83	0.87	0.89	0.33	1.00	0.78	0.93	0.71
Dichondra species A		1	.	.	.	0.11	.	.	.	.	0.05
Polymeria longifolia	H	2	.	.	.	0.22	.	.	.	.	0.10
CRASSULACEAE											
Crassula sieberiana		10	.	0.67	0.06	0.44	.	.	.	0.14	0.38
CUCURBITACEAE											
Zehneria cunninghamii		1	.	0.17	.	.	.	.	.	.	0.05
DILLENIACEAE											
Hibbertia acicularis	M	+									
Hibbertia obtusifolia		29	.	0.33	0.71	0.56	.	0.67	0.78	0.64	0.43
Hibbertia obtusifolia-linearis		5	.	.	0.16	.	.	0.17	0.11	0.21	.
EPACRIDACEAE											
Acrotriche serrulata	H	7	.	.	0.16	0.22	.	.	.	0.21	0.19
Leucopogon hookeri		5	.	0.17	0.13	.	.	.	0.11	0.14	0.10
Leucopogon lanceolatus		7	.	0.17	0.19	.	.	0.17	0.11	0.29	0.05

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
Melichrus urceolatus		6	.	.	0.10	0.33	.	.	0.11	0.07	0.19
EUPHORBIACEAE											
Bertya sp.	H	+	.	.	.	.	+	.	.	.	+
Beyeria viscosa	H	+	.	.	.	.	+	.	.	.	+
Omalanthus populifolius		+	+	.	.	.	.	.	.	+	.
Phyllanthus virgatus	H	1	.	.	.	0.11	.	.	.	.	0.05
Poranthera microphylla		14	.	.	0.35	0.33	.	0.33	0.44	0.29	0.19
FABACEAE–CAESALPINOIDEAE											
Senna aciphylla	H	+	.	.	.	+	.	.	.	.	+
FABACEAE–FABOIDEAE											
Daviesia genistifolia	H	3	.	0.17	0.03	0.11	.	.	.	.	0.14
Daviesia mimosoides	H	+	.	+	.	.	.	.	.	+	.
Daviesia ulicifolia		3	.	.	0.10	.	.	.	0.11	0.14	.
Desmodium brachypodum		3	.	.	.	0.33	.	.	.	.	0.14
Desmodium varians		38	.	1.00	0.74	1.00	.	0.67	1.00	0.57	0.81
Glycine clandestina	H	38	.	0.83	0.81	0.89	.	0.67	0.89	0.86	0.67
Hardenbergia violacea		11	.	0.17	0.23	0.33	.	0.33	0.11	0.29	0.19
Hovea lanceolata	H	1	.	0.17	.	.	.	.	.	.	0.05
Indigofera adesmiifolia	H	+	.	.	.	.	+	.	.	.	+
Indigofera australis		1	.	.	0.03	.	.	0.17	.	.	.
Lespedeza juncea subsp. *sericea*		1	.	0.17	.	.	.	.	.	.	0.05
**Lotus corniculatus*	H	1	.	0.17	.	.	.	.	.	.	0.05
Pultenaea polifolia	H	1	.	.	.	.	0.33	.	.	.	0.05
Pultenaea retusa	H	1	.	.	.	0.11	.	.	.	.	0.05
Pultenaea species G	H	1	.	.	0.03	.	.	.	.	0.07	.
Pultenaea species I	H	2	.	0.17	.	0.11	.	.	.	.	0.10
Swainsona galegifolia	H	24	.	1.00	0.39	0.67	.	0.50	0.44	0.36	0.57
**Trifolium arvense*		4	.	0.17	.	0.33	.	.	.	.	0.19
**Trifolium campestre*		2	.	.	.	0.22	.	.	.	.	0.10
**Trifolium glomeratum*		2	.	.	.	0.22	.	.	.	.	0.10
**Trifolium repens*		13	.	0.67	0.06	0.44	1.00	.	.	0.07	0.57
FABACEAE–MIMOSOIDEAE											
Acacia dealbata	H	19	.	.	0.58	.	0.33	0.83	0.56	0.57	0.05
Acacia implexa		1	.	.	.	0.11	.	.	.	.	0.05
Acacia melanoxylon		14	1.00	0.83	0.23	0.11	.	.	0.22	0.29	0.38
Acacia neriifolia		1	.	.	.	0.11	.	.	.	.	0.05

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
Acacia paradoxa	H	1	.	.	.	0.11	.	.	.	.	0.05
GENTIANACEAE											
**Centaurium erythraea*	H	6	.	0.50	.	0.33	.	.	.	.	0.29
GERANIACEAE											
**Erodium cicutarium*	M	+									
Geranium homeanum	H	6	.	0.17	0.06	0.33	.	0.17	0.11	.	0.19
Geranium potentilloides	H	13	.	0.50	0.26	0.22	.	0.17	0.11	0.36	0.29
Geranium retrorsum	H	4	.	0.33	0.03	0.11	.	.	0.11	.	0.14
Geranium solanderi var. *grande*	H	1	.	.	0.03	.	.	.	.	.	0.05
Geranium solanderi var. *solanderi*	H	10	.	0.33	0.23	0.11	.	0.33	0.11	0.21	0.19
GOODENIACEAE											
Goodenia gracilis	H	+	.	+	.	.	.	.	.	+	.
HALORAGACEAE											
Gonocarpus humilis	H	15	.	0.33	0.39	0.11	.	0.33	0.11	0.50	0.24
Gonocarpus micranthus subsp. *micranthus*		1	.	.	.	.	0.33	.	.	.	0.05
Haloragis heterophylla		7	.	0.33	0.03	0.11	1.00	.	.	0.07	0.29
Myriophyllum pedunculatum	H	3	.	0.17	.	.	0.67	.	.	.	0.14
Myriophyllum variifolium	H	1	.	0.17	.	.	.	.	.	.	0.05
Myriophyllum verrucosum	H	1	.	0.17	.	.	.	.	.	.	0.05
LAMIACEAE											
Ajuga australis		30	.	0.17	0.74	0.67	.	0.33	0.89	0.79	0.43
**Lamium amplexicaule*	M										
**Marrubium vulgare*	M										
Mentha diemenica	H	8	.	0.33	0.10	0.33	.	.	.	0.07	0.33
Plectranthus parviflorus		4	.	0.33	.	0.22	.	.	.	.	0.19
Prostanthera ?caerulea	H	+	.	.	.	.	+	.	.	.	+
Prostanthera lasianthos		1	.	0.17	.	.	.	.	.	.	0.05
Prunella vulgaris		2	.	0.33	.	.	.	.	.	.	0.10
Scutellaria humilis		2	.	.	0.03	0.11	.	0.17	.	.	0.05
Scutellaria mollis	H	2	.	0.17	0.03	.	.	0.17	.	.	0.05
Teucrium species D	H	+	.	.	.	.	+	.	.	.	+
LOBELIACEAE											
Isotoma fluviatilis subsp. *borealis*	H	4	.	0.17	.	.	1.00	.	.	.	0.19

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
Lobelia gibbosa		+	.	+	.	.	.	.	+	.	.
LORANTHACEAE											
Amyema congener	H	1	.	.	.	0.11	.	.	.	.	0.05
Amyema miquelii	H	1	.	.	.	0.11	.	.	.	.	0.05
Amyema pendulum subsp. *pendulum*		4	.	.	0.13	.	.	.	.		0.29.
MYRSINACEAE											
Rapanea howittiana		1	.	0.17	.	.	.	.	.	.	0.05
MYRTACEAE											
Angophora floribunda		8	.	0.50	.	0.56	.	.	.	.	0.38
Callistemon pallidus	H	3	.	0.50	.	.	.	.	.	.	0.14
Callistemon sieberi	H	1	.	0.17	.	.	.	.	.	.	0.05
Eucalyptus bridgesiana	H	6	.	0.17	0.06	0.33	.	.	.	0.07	0.24
Eucalyptus dalrympleana subsp. *heptantha*	H	10	.	0.17	0.23	.	0.67	0.17	0.22	0.21	0.19
Eucalyptus goniocalyx	M	+									
Eucalyptus laevopinea	H	35	.	0.83	0.71	0.89	.	1.00	1.00	0.43	0.67
Eucalyptus melliodora		8	.	.	0.03	0.78	.	.	.	.	0.38
Eucalyptus moluccana	M	+									
Eucalyptus nobilis	H	20	1.00	0.67	0.48	.	.	0.50	0.44	0.57	0.24
Eucalyptus nortonii	H	3	.	.	.	0.33	.	.	.	.	0.14
Eucalyptus pauciflora		10	.	0.17	0.29	.	.	0.17	0.11	0.50	0.05
Eucalyptus praecox	H	3	.	.	0.10	.	.	.	0.11	0.07	0.05
Eucalyptus stellulata		11	.	0.33	0.26	.	0.33	0.33	0.11	0.29	0.19
Leptospermum gregarium	H	5	.	0.33	.	.	1.00	.	.	.	0.24
Leptospermum polygalifolium subsp. *montanum*	H	1	.	.	.	.	0.33	.	.	.	0.05
OLEACEAE											
Notelaea microcarpa var. *microcarpa*		2	.	0.17	0.03	.	.	0.17	.	.	0.05
ONAGRACEAE											
Epilobium billardieranum subsp. *hydrophilum*	H	5	.	0.67	.	.	0.33	.	.	.	0.24
Epilobium billardierianum subsp. *cinereum*	H	24	.	0.83	0.48	0.33	0.33	0.50	0.44	0.43	0.52
Epilobium hirtigerum	H	2	.	.	.	.	0.67	.	.	.	0.10
OXALIDACEAE											
Oxalis chnoodes		6	.	.	0.16	0.11	.	.	0.22	0.14	0.10

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
PHYTOLACCACEAE											
*_Phytolacca octandra_		1	.	.	0.03	.	.	.	0.11	.	.
PITTOSPORACEAE											
Billardiera scandens		2	.	.	0.06	.	.	0.17	0.11	.	.
Bursaria spinosa		11	.	.	0.16	0.67	.	.	0.22	0.14	0.33
Pittosporum undulatum		5	.	0.17	.	0.44	.	.	.	.	0.24
PLANTAGINACEAE											
Plantago debilis	H	14	1.00	0.50	0.06	0.89	.	.	.	0.14	0.57
Plantago varia	H	2	.	.	0.03	0.11	.	.	.	0.07	0.05
POLYGALACEAE											
Polygala japonica		7	.	.	0.10	0.44	.	0.17	.	0.14	0.19
POLYGONACEAE											
Persicaria decipiens	H	2	.	0.33	.	.	.	.	.	.	0.10
*_Polygonum aviculare_	H	+	.	+	.	.	.	+	.	.	.
Rumex brownii		15	.	0.83	0.13	0.44	0.67	0.17	.	0.14	0.57
PROTEACEAE											
Hakea microcarpa		2	.	.	.	.	0.67	.	.	.	0.10
Lomatia arborescens		7	1.00	0.50	0.10	.	.	0.17	.	0.14	0.19
RANUNCULACEAE											
Clematis aristata		12	1.00	0.33	0.19	0.33	.	0.17	0.33	0.14	0.29
Clematis glycinoides		7	.	0.33	.	0.56	.	.	.	.	0.33
Clematis microphylla var. microphylla		1	.	.	0.03	.	.	.	0.11	.	.
Ranunculus amphitrichus	H	1	.	0.17	.	.	.	.	.	.	0.05
Ranunculus inundatus	H	1	.	0.17	.	.	.	.	.	.	0.05
Ranunculus lappaceus		34	.	0.50	0.84	0.56	.	0.83	0.89	0.79	0.48
RHAMNACEAE											
Cryptandra amara var. amara	H	1	.	.	.	0.11	.	.	.	.	0.05
Discaria pubescens	H	1	.	.	0.03	.	.	.	.	0.07	.
ROSACEAE											
Acaena echinata	H	5	.	.	0.03	0.44	.	.	.	0.07	0.19
Acaena novae-zelandiae		39	.	1.00	0.74	0.89	0.67	1.00	0.44	0.79	0.86
Geum urbanum	H	2	.	0.33	.	.	.	.	.	.	0.10
*_Rosa rubiginosa_	H	2	.	0.17	0.03	.	.	.	.	0.07	0.05
*_Rubus discolor-ulmifolius_		2	.	0.34	.	.	.	.	.	.	0.10
Rubus parvifolius		13	.	1.00	0.16	0.22	.	.	0.11	0.21	0.43

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
RUBIACEAE											
Asperula conferta	H	33	.	0.50	0.81	0.56	.	0.83	0.67	0.86	0.48
Coprosma hirtella	M	+									
Coprosma quadrifida		3	.	0.33	0.03	.	.	.	0.11	.	0.10
Galium binifolium		1	.	.	.	0.11	.	.	.	.	0.05
Galium ciliare	H	4	.	.	0.10	0.11	.	.	0.11	0.14	0.05
Galium gaudichaudii	H	4	.	.	0.03	0.33	.	.	.	0.07	0.14
Galium migrans	H	20	1.00	0.83	0.35	0.33	.	0.33	0.44	0.36	0.43
RUTACEAE											
Correa reflexa var. *reflexa*		2	.	0.17	.	0.11	.	.	.	.	0.10
SANTALACEAE											
Exocarpos cupressiformis		2	.	.	0.06	.	.	.	.	0.14	.
SAPINDACEAE											
Dodonaea viscosa subsp. *angustissima*	H	1	.	0.17	.	.	.	.	.	.	0.05
SCROPHULARIACEAE											
Derwentia derwentiana	H	1	.	0.17	.	.	.	.	.	.	0.05
Euphrasia collina subsp. *paludosa*	H	+	.	.	+	+	.	.	.	.	+
Glossostigma diandrum	H	1	.	0.17	.	.	.	.	.	.	0.05
Gratiola peruviana	H	4	.	0.67	.	.	.	.	.	.	0.19
**Verbascum virgatum*		1	.	.	0.03	.	.	.	.	0.07	.
Veronica calycina	H	36	.	0.33	0.84	0.89	.	0.83	1.00	0.71	0.57
SOLANACEAE											
Solanum opacum		7	1.00	.	0.19	.	.	.	0.33	0.21	0.05
Solanum prinophyllum		1	.	.	.	0.11	.	.	.	.	0.05
Solanum pungetium		3	.	.	0.10	.	.	0.17	0.11	0.07	.
STERCULIACEAE											
Brachychiton populneus		1	.	.	.	0.11	.	.	.	.	0.05
STYLIDIACEAE											
Stylidium graminifolium		2	.	.	0.06	.	.	.	.	0.14	.
THYMELAEACEAE											
Pimelea curviflora subsp. *curviflora*	H	3	.	0.17	0.03	0.11	.	.	0.11	.	0.10
Pimelea ligustrina subsp. *ligustrina*	H	4	.	0.67	.	.	.	.	.	.	0.19
Pimelea linifolia	M	+									

			Floristic Group					**Logging Category**			
		Tot. freq.	**MF (1)**	**RpF (6)**	**PGF (31)**	**DW (9)**	**Sw (3)**	**L1 (6)**	**L2 (9)**	**UL1 (14)**	**UL2 (21)**
Pimelea microcephala	H	2	.	.	0.03	0.11	.	0.17	.	.	0.05
Pimelea strigosa	H	3	.	.	.	0.33	.	.	.	.	0.14
URTICACEAE											
Australina pusilla	H	5	1.00	0.67	.	.	.	.	.	.	0.24
Urtica incisa		15	1.00	0.83	0.23	0.22	.	0.33	0.22	0.21	0.38
VERBENACEAE											
**Verbena bonariensis*	H	5	.	0.33	.	0.33	.	.	.	.	0.24
**Verbena officionalis*		+	.	.	.	+	.	.	.	.	+
**Verbena rigida*		1	.	.	.	0.11	.	.	.	.	0.05
VIOLACEAE											
Hymenanthera dentata		7	1.00	0.67	.	0.22	.	.	.	.	0.33
Viola betonicifolia		35	.	0.50	0.84	0.67	.	0.83	0.89	0.79	0.52
Viola hederacea		6	.	0.33	0.13	.	.	0.17	0.22	0.07	0.10
Class MAGNOLIOPSIDA–LILIIDAE											
ANTHERICACEAE											
Arthropodium milleflorum		35	.	1.00	0.65	0.89	0.33	0.83	0.67	0.64	0.71
Arthropodium species B	H	2	.	.	.	0.11	0.33	.	.	.	0.10
Caesia calliantha	H	2	.	.	0.06	.	.	.	.	0.14	.
ARACEAE											
Gymnostachys anceps		1	.	.	0.03	.	.	0.17	.	.	.
ASPHODELACEAE											
Bulbine bulbosa		3	.	0.17	0.06	.	.	.	.	0.14	0.05
COLCHICACEAE											
Wurmbea dioica	M	+									
CYPERACEAE											
Bulbostylis densa		1	.	.	.	.	0.33	.	.	.	0.05
Carex appressa		1	.	0.17	.	.	.	.	.	.	0.05
Carex breviculmis		37	.	0.83	0.81	0.67	0.33	1.00	0.67	0.86	0.62
Carex chlorantha	H	1	.	0.17	.	.	.	.	.	.	0.05
Carex declinata		1	.	0.17	.	.	.	.	.	.	0.05
Carex fascicularis		1	.	0.17	.	.	.	.	.	.	0.05
Carex incomitata	H	9	.	0.33	0.16	0.22	.	0.17	0.22	0.14	0.19
Cyperus lucidus		1	.	0.17	.	.	.	.	.	.	0.05
Cyperus sanguinolentus	H	4	.	0.17	.	.	1.00	.	.	.	0.19
Cyperus sphaeroideus		4	.	0.17	.	.	1.00	.	.	.	0.19

			Floristic Group					Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
Eleocharis dietrichiana	H	3	.	0.17	.	.	0.67	.	.	.	0.14
Fimbristylis dichotoma	H	1	.	.	.	0.11	.	.	.	.	0.05
Isolepis australiensis	H	1	.	.	.	.	0.33	.	.	.	0.05
Isolepis cernua	H	1	.	0.17	.	.	.	.	.	.	0.05
Isolepis hookeriana	H	1	.	.	.	.	0.33	.	.	.	0.05
Isolepis inundatus	H	1	.	.	.	.	0.33	.	.	.	0.05
Isolepis sp.	H	2	.	0.33	.	.	.	.	.	.	0.10
Lepidosperma laterale		7	.	.	0.06	0.56	.	0.17	.	0.07	0.24
Schoenus apogon		11	.	0.50	0.06	0.33	1.00	.	.	0.14	0.43
HYPOXIDACEAE											
Hypoxis hygrometrica		2	.	.	.	.	0.67	.	.	.	0.10
IRIDACEAE											
Libertia paniculata		3	.	0.50	.	.	.	.	.	.	0.14
JUNCACEAE											
Juncus alexandri subsp. *melanobasis*	H	2	.	0.33	.	.	.	.	.	.	0.10
**Juncus bufonius*	H	1	.	.	.	.	0.33	.	.	.	0.05
Juncus filicaulis	M	+									
Juncus fockei	H	4	.	0.17	.	.	1.00	.	.	.	0.19
Juncus pauciflorus	M	+									
Juncus polyanthemus	M	+									
Juncus sandwithii	H	2	.	0.33	.	.	.	.	.	.	0.10
Juncus vaginatus		1	.	0.17	.	.	.	.	.	.	0.05
Luzula flaccida	H	35	.	0.33	0.80	0.67	0.67	1.00	0.67	0.78	0.57
Juncus spp.		2	.	0.17	.	.	0.33	.	.	.	0.10
LEMNACEAE											
Lemna trisulca	H	1	.	0.17	.	.	.	.	.	.	0.05
LOMANDRACEAE											
Lomandra confertifolia subsp. *pallida*		2	.	.	.	0.22	.	.	.	.	0.10
Lomandra filiformis		12	.	.	0.35	0.11	.	0.50	0.33	0.21	0.14
Lomandra longifolia		32	.	1.00	0.71	0.44	.	0.67	0.56	0.86	0.52
Lomandra longifolia –*confertifolia* intergrade	H	2	.	.	.	0.22	.	.	.	.	0.10
Lomandra multiflora	H	6	.	.	0.10	0.33	.	0.17	0.11	0.07	0.14
LUZURIAGACEAE											
Eustrephus latifolius		34	1.00	0.83	0.71	0.67	.	0.50	1.00	0.64	0.62

			Floristic Group					**Logging Category**			
		Tot. freq.	**MF (1)**	**RpF (6)**	**PGF (31)**	**DW (9)**	**Sw (3)**	**L1 (6)**	**L2 (9)**	**UL1 (14)**	**UL2 (21)**
ORCHIDACEAE											
Acianthus fornicatus		2	.	.	0.03	0.11	.	.	.	.	0.10
Acianthus spp.		2	.	.	0.03	0.11	.	.	.	0.07	0.05
Chiloglottis trilabra	H	8	.	.	0.26	.	.	0.33	0.33	0.21	.
Corybas fimbriatus		2	.	.	0.06	.	.	0.33	.	.	.
Cyrtostylis reniformis	M	+									
Dendrobium cucumerinum		+	+	.	.	.	.	.	.	+	.
Dipodium roseum	H	3	.	.	0.10	.	.	.	0.11	0.14	.
Diuris sulphurea		1	.	.	0.03	.	.	0.17	.	.	.
Eriochilus cucullatus	M	+									
Genoplesium sp.		1	.	.	0.03	.	.	.	.	0.07	.
Pterostylis coccina		12	.	0.33	0.32	.	.	.	0.22	0.50	0.14
Pterostylis decurva		1	.	.	0.03	.	.	.	.	0.07	.
Pterostylis laxa		2	.	.	.	0.22	.	.	.	.	0.10
Pterostylis nutans	M	+									
Pterostylis obtusa		1	.	0.17	.	.	.	.	.	.	0.05
Pterostylis species B		7	.	.	0.13	0.33	.	.	0.22	0.14	0.14
Spiranthes sinensis		5	.	0.33	.	.	1.00	.	.	.	0.24
PHORMIACEAE											
Dianella caerulea		3	.	.	0.10	.	.	.	0.11	0.14	.
Dianella longifolia		7	.	.	0.23	.	.	0.17	0.22	0.21	0.05
Dianella revoluta		1	.	.	.	0.11	.	.	.	.	0.05
POACEAE											
Agrostis avenacea	H	4	.	0.17	0.03	.	0.67	.	.	0.07	0.14
Agrostis venusta	H	3	.	0.33	0.03	.	.	.	.	.	0.14
**Anthoxanthum odoratum*		1	.	.	.	0.11	.	.	.	.	0.05
Aristida ramosa var. *speciosa*	H	1	.	.	.	0.11	.	.	.	.	0.05
Bothriochloa macra	H	4	.	0.17	.	0.33	.	.	.	.	0.19
Cymbopogon refractus		1	.	.	.	0.11	.	.	.	.	0.05
Danthonia eriantha	H	1	.	.	.	0.11	.	.	.	.	0.05
Danthonia laevis	H	17	.	0.17	0.45	0.22	.	.	0.44	0.57	0.24
Danthonia pilosa var. *pilosa*	H	10	.	0.17	0.26	0.11	.	.	0.33	0.36	0.10
Danthonia racemosa	H	25	.	0.33	0.52	0.67	0.33	0.33	0.44	0.57	0.52
Dichanthium sericeum	H	1	.	.	.	0.11	.	.	.	.	0.05
Dichelachne crinita	H	3	.	.	0.10	.	.	0.33	.	0.07	.
Dichelachne micrantha		24	.	0.17	0.52	0.67	0.33	.	0.44	0.71	0.48

		Floristic Group						Logging Category			
		Tot. freq.	MF (1)	RpF (6)	PGF (31)	DW (9)	Sw (3)	L1 (6)	L2 (9)	UL1 (14)	UL2 (21)
Dichelachne rara	H	6	.	0.17	0.10	.	0.67	0.17	.	0.07	0.19
Echinopogon caespitosus		4	.	0.33	0.03	0.11	.	0.17	.	.	0.14
Echinopogon cheelii	H										
Echinopogon ovatus	H	41	1.00	1.00	0.84	0.89	.	1.00	0.89	0.71	0.81
Elymus scaber var. *scaber*		27	.	1.00	0.45	0.78	.	0.33	0.44	0.50	0.67
Eragrostis benthamii	H	1	.	.	.	.	0.33	.	.	.	0.05
Festuca asperula	H	1	.	.	0.03	.	.	.	.	0.07	.
Glyceria latispicea	H	3	.	.	0.10	.	.	.	0.11	0.14	.
Microlaena stipoides		43	1.00	1.00	0.87	0.89	0.33	0.83	0.89	0.86	0.86
Oplismenus imbecillus		3	.	0.17	.	0.22	.	.	.	.	0.14
Panicum effusum		1	.	.	0.03	.	.	0.17	.	.	.
Paspalidium gracile	H	1	.	.	.	0.11	.	.	.	.	0.05
**Poa annua*	M	+									
Poa labillardieri		30	.	0.83	0.68	0.44	.	0.67	0.67	0.71	0.48
Poa sieberiana var. *sieberiana*		21	.	0.33	0.45	0.44	0.33	0.33	0.44	0.50	0.38
Sorghum leiocladum		1	.	.	0.03	.	.	.	.	0.07	.
Stipa rudis subsp. *nervosa*	H	18	.	0.33	0.42	0.33	.	0.67	0.44	0.29	0.29
POTAMOGETONACEAE											
Potamogeton tricarinatus	H	1	.	0.17	.	.	.	.	.	.	0.05
SMILACACEAE											
Smilax australis		14	1.00	0.50	0.32	.	.	0.33	0.44	0.29	0.19
XANTHORRHOEACEAE											
Xanthorrhoea glauca subsp. *glauca*		+	+	+	.	.	.	.	+	+	+

Note: The following additional species or names are recorded in the Management Plan (Forestry Commission of NSW 1982) but are excluded from the above list for various reasons as stated.

Asperula scoparia	Possibly confused with the related *A. conferta*.
Callistemon citrinus	Probable misidentification, from confusion with *C. pallidus* which is common in the area.
Callistemon shiressii	Misidentification (confused with *C. sieberi*).
Cerastium glomeratum	Possibly confused with *C. fontanum* subsp. *vulgare*.
Dianella laevis	Synonymous with *D. longifolia*.
Erodium malacoides	This naturalised species is otherwise recorded only from the South Western Plains subdivision in NSW, and the record from Coolah Tops requires confirmation.
Eucalyptus mannifera subsp. *maculosa*	Populations in the area are currently referred to *E. praecox*.
E. viminalis	Probably *E. nobilis*, a recently described species common in the area.
Leptospermum myrtifolium	Coolah Tops populations now referred to *L. gregarium*.
Leucopogon suaveolens	Synonymous with *L. hookeri*.
Haloragis tetragyna	This species (syn. *Gonocarpus tetragynus*) and *G. humilis* were not clearly distinguishable during survey.
Hypolepis punctata	Synonymous with *H. glandulifera*.
Sium latifolium	Synonymous with *Berula erecta*.
Teucrium corymbosum	Possibly confused with the recently recognized T. species D. Occurrence at Coolah Tops requires confirmation.
Veronica arvensis	This naturalised species may have been confused with the native *V. calycina* and its occurrence in the area requires confirmation.
Xanthorrhoea australis	Probable misidentification of *X. glauca*. *X. australis* is not otherwise recorded north of Nowra.

Appendix 2. Location and survey date for flora survey plots

Plot	Date	Zone	Map	AMG E	AMG N	Altitude (m)
BUN001	19930222	56	8934	219100	6488330	1070
BUN002	19930224	56	8934	219280	6489400	1060
BUN003	19930224	56	8934	218900	6489400	1050
BUN004	19930226	55	8834	784150	6486550	1000
BUN005	19930228	56	8934	216950	6488230	1040
BUN006	19930925	56	8934	221580	6485750	1150
BUN007	19930925	56	8934	216430	6485950	1080
BUN008	19930925	56	8934	215250	6484980	1050
OL1-3	19930227	55	8834	782750	6484000	1050
OL2-3	19930228	56	8934	217100	6484780	1110
OL3-3	19930227	56	8934	223680	6483550	1140
OL4-3	19930301	56	8934	233530	6476230	1140
RL1-3	19930228	56	8934	216380	6484180	1070
RL2-3	19930224	56	8934	216400	6485350	1050
RL3-3	19930227	56	8934	225830	6480950	1160
RL4-3	19930226	56	8934	224450	6481250	1160
UL1-3	19930228	56	8934	216200	6483630	1070
UL2-3	19930227	56	8934	226480	6482500	1180
UL3-3	19930226	56	8934	229980	6481680	1190
UL4-2	19930301	56	8934	234550	6475630	1120
WAR001	19930223	56	8934	235150	6474480	880
WAR002	19930223	56	8934	235000	6475200	1050
WAR003	19930223	56	8934	233550	6475350	830
WAR004	19930223	56	8934	233130	6477130	1120
WAR005	19930225	56	8934	219100	6481130	1070
WAR006	19930225	56	8934	220430	6482930	1090
WAR007	19930225	56	8934	219380	6482450	1080
WAR008	19930225	56	8934	218250	6483930	1070
WAR009	19930225	56	8934	218830	6484950	1100
WAR010	19930225	56	8934	220080	6485550	1120
WAR011	19930228	56	8934	217280	6482530	1040
WAR012	19930226	56	8934	232350	6478350	1080
WAR013	19930226	56	8934	230600	6479750	1120
WAR014	19930226	56	8934	227950	6481580	1200
WAR015	19930227	55	8834	782730	6482680	950
WAR016	19930227	55	8834	785780	6482950	940
WAR017	19930227	56	8934	224100	6482830	980
WAR018	19930228	56	8934	218550	6484850	1090
WAR019	19930301	56	8934	230580	6475200	1120
WAR020	19930301	56	8934	238700	6475380	1100
WAR021	19930301	56	8934	237730	6475200	1140
WAR022	19930301	56	8934	231450	6476680	1240
WAR026	19940517	56	8934	238230	6471380	760
WAR027	19940517	56	8934	234800	6471550	660
WAR028	19940518	56	8934	229430	6748100	800
WAR029	19940518	56	8934	227930	6476380	770
WAR030	19940519	56	8934	223280	6482200	900
WAR031	19940519	56	8934	228880	6476730	1060
WAR032	19940519	56	8934	232880	6774900	740
WAR033	19940519	56	8934	233130	6473230	670

SHORT COMMUNICATION

Range extensions for several restricted plant species, Northern Tablelands, New South Wales

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Introduction

Several rare vascular plant species have been recorded from Butterleaf State Forest on the Northern Tablelands of New South Wales, particularly in the vicinity of Mt Scott (Binns 1992). Based on these observations further field investigations of the Mt Scott area were made during April and July, 1996. Additional distributional records of rare species, or those not formerly known from the Northern Tablelands, form the basis of material presented here. Vouchers of all species discussed have been lodged at the Department of Botany, University of New England, The National Herbarium of NSW and the Herbarium of the North Coast Regional Botanic Garden, Coffs Harbour. Changes to the ROTAP code of some species are suggested where appropriate.

Locality

Butterleaf State Forest lies 40 kilometres north-east of Glen Innes on the Northern Tablelands of New South Wales, encompassing 5156 hectares of forest on terrain ranging from undulating to hilly over an altitudinal range of 900 metres to over 1300 metres above sea level. The underlying geology is comprised primarily of granites of the New England Batholith, viz. coarse-grained Kingsgate Granite and medium to coarse-grained adamellite. Some areas of Butterleaf State Forest are on fine-grained metasediments and Emmaville Volcanics. The main forest tree species are *Eucalyptus campanulata* and *E. obliqua*. Less frequent overstorey species include *E. nobilis, E. cameronii, E. brunnea, E. laevopinea, E. dalrympleana* subsp. *heptantha* and *E. radiata* subsp. *sejuncta*. Disturbances have occurred including logging, grazing and burning.

Mount Scott (29°31'S 152°01'E), a prominent feature in the north western portion of the state forest, represents a large outcrop of Kingsgate Granite extending over an area approximately 1.5 km in length and 0.5 km in width, and rising to 1358 metres above sea level at the trig. station. The vegetation on these outcrops includes monospecific stands of *Eucalyptus codonocarpa* as mallee woodland and mixed heathlands dominated by *Leptospermum novae-angliae, Calytrix tetragona, Kunzea obovata* and *Leucopogon neo-anglicus*.

The environmental impact statement prepared for the Glen Innes forest management area (Manidis Roberts 1992) proposed the reservation of Mt Scott and environs for the protection of significant vascular plant species known to occur there. This area has subsequently been classified by the Forestry Commission of NSW as Preserved Native Forest (FCNSW 1993) to protect its biological values. This means that the area is managed as a Flora Reserve, but does not have the formal protection afforded a Flora Reserve.

Notes

1. *Brachyloma saxicola*

Restricted to granite outcrops and known to occur at Gibraltar Range NP, Guy Fawkes River NP, Crown Mountain Flora Reserve, Backwater, Torrington Regional Reserve, Mount Jondol and Bolivia Hill, all within the north-east of New South Wales.

Hunter and Williams (1994), following Williams and Wissmann (1991), suggested the ROTAP code of 2VC (Briggs & Leigh 1996). Quinn et al. (1995) have subsequently suggested the code 3RCi. With Torrington Regional Reserve being recently moved to the control of the New South Wales National Parks and Wildlife Service, and the addition of this population on Mt Scott, where the species is reasonably common, the conservation of this species is adequate and therefore a 3RCa code would be appropriate.

2. *Cryptandra lanosiflora*

This species is restricted to rocky exposed areas and is known from Girraween NP in Queensland, Gibraltar Range NP, New England NP, Werrikimbe NP, Black Mountain at Glen Elgin SF, Backwater, Bolivia Hill, the Liverpool Range and Parlour Mountains in New South Wales.

This additional population of *Cryptandra lanosiflora* should not affect its current ROTAP coding of 3RCa.

3. *Eriostemon myoporoides* subsp. *epilosus*

Restricted to exposed rocky outcrops, this species has been recorded from Girraween NP in Queensland, Bald Rock NP, Boonoo Boonoo NP, Demon Nature Reserve, Boonoo SF and Bolivia Hill in New South Wales.

This species was found to be common on the rock platforms of Mt Scott and in similar habitat on adjacent private properties (Hunter, unpublished data). With the addition of this protected population to the large reserved populations in Girraween and Bald Rock National Parks, the present ROTAP code of 3RC- should be changed to 3RCa.

4. *Eucalyptus codonocarpa*

Populations of this species are known from Girraween NP in Queensland, Cathedral Rocks NP, Crown Mountain Flora Reserve, Backwater and Gibraltar Range NP in New South Wales.

An estimated 5 hectares of pure stands of *Eucalyptus codonocarpa* occur around the summit of Mt Scott, the estimated population size being about 8000 to 10 000 plants.

Some plants have been destroyed during construction of the trig. station at the summit of Mt Scott. Some stands have been burnt and are regenerating successfully. A ROTAP code of 3RC- has been given to this species. With this additional record and the subsequent reservation of this area, preservation is adequate for this species and the ROTAP code should be 3RCa.

5. *Eucalyptus retinens*

Eucalyptus retinens occurs primarily on the sides of steep gorges to the east of Armidale at Enmore, Bakers Creek Falls, Hillgrove, and Wollomombi in Oxley Wild Rivers NP and Chaelundi Falls in Guy Fawkes River NP in New South Wales. It was recently recorded from the Kingsgate Mine area east of Glen Innes (Sheringham & Westaway 1995).

Small populations of *Eucalyptus retinens* were found at the western end of Butterleaf State Forest and in Brother State Forest (30 km east of Glen Innes) and represent a significant extension and disjunction in the distribution of this species. The habitats in which these populations were found, i.e. open forest on undulating terrain, are unlike that previously known for this species. The identity of vouchers has been confirmed (Ken Hill, pers. comm.). Johnson & Hill (1990) did not assign a ROTAP code for this species and none have subsequently been suggested. Sheringham and Westaway (1995) regard *E. retinens* as regionally uncommon, reaching its northern distributional limit in upper north-east New South Wales. We believe that the distribution of this species is restricted and warrants the code 3RC-.

6. *Lasiopetalum ferrugineum* var. *cordatum*

Although common in Victoria and eastern and southern New South Wales, this species has not been recorded for the Northern Tablelands of New South Wales. The discovery of populations on Mt Scott and also on similar rock outcrops on adjacent private properties (Hunter, unpublished data) have extended the distribution of this species onto the Northern Tablelands of New South Wales.

7. *Leucopogon cicatricatus*

Several disjunct populations are known for this species with localities being recorded from Girraween NP (Hunter 1996) and Mt Barney NP in Queensland, Cathedral Rocks NP, New England NP, and Rowleys Rock Flora Reserve, Dingo/Bulga SF (Binns & Chapman 1992) in New South Wales.

Large numbers of this species were found on Mt Scott, in crevices of exposed areas of the outcrop. The population was estimated to be in excess of 500 individuals. A ROTAP code of 3RC- has been given to this species. With the addition of this large population in the newly designated forest reserve and the recently discovered population in Girraween NP (Hunter 1996) the reservation of this species is adequate and the code 3RCa is appropriate.

8. *Muehlenbeckia costata*

This species has been recorded from Girraween NP in Queensland, the Blue Mountains, Mount Kaputar NP, Bald Rock NP (Hunter 1995) and Crown Mountain Flora Reserve (Binns 1992; Hunter 1995) in New South Wales.

Muehlenbeckia costata was found to be abundant in recently burnt areas on the western face of Mt Scott. Many of the plants were amongst the resprouting stands of *Eucalyptus codonocarpa*. A single plant was also recorded by Richards (1996) in a recently burnt area on Garrett Trig. in Butterleaf SF. This species has a current ROTAP code of 3KC-. Recent discoveries of large populations in reserved areas as well as controlled burns and germination experiments by Hunter (unpublished data) have significantly improved the information known about this species. Although it has a restricted habitat preference and is vulnerable to inappropriate fire regimes, this species is adequately reserved, and a code of 3VCa is appropriate. Note that the 'vulnerable' coding should be retained as the ephemeral nature of this species poses fire management problems and creates extreme fluctuations in population size.

Discussion

The vegetation found on outcropping granite at Mt Scott represents a link in the granitic outcrop flora of the New England region of New South Wales. Crown Mountain Flora Reserve north east of Guyra, and Girraween and Bald Rock National Parks north of Tenterfield contain large expanses of granite outcrops at high altitudes (above 1100 metres). Mt Scott is the only large granite outcrop between these two regions at high elevations on the Northern Tablelands. It is probably for this reason that rare species such as *Eucalyptus codonocarpa, Leucopogon cicatricatus* and *Muehlenbeckia costata* occur there. The vegetation communities on Mt Scott are closely allied with those found within Crown Mountain Flora Reserve (Hunter, unpublished data).

The Mt Scott area has made a significant improvement to the conservation status of several ROTAP species. This highlights the need for continued evaluation of the distribution and biology of the plant species of areas such as rock outcrops, which behave as ecologically distinct 'islands' supporting an interesting and unique flora. It is important that management decisions concerning such areas are made using as up-to-date information as possible, hence the need to report on significant locations like Mt Scott.

It is appropriate that the Mt Scott environs has been recognised as an area of significance and has been classified as Preserved Native Forest, although elevation to Flora Reserve status would be highly desirable. However, at present there are no threats to the populations of rare plant species that occur there and if management practices do not change the present reservation status will provide adequate protection.

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Manuscript accepted 16 April 1997

SHORT COMMUNICATION

New distributions of *Leptospermum namadgiensis* and *Olearia rhizomatica* on Yaouk Peak (Southern Tablelands, NSW).

Bernard Pfeil

John Ray Herbarium, Macleay Building A12, University of Sydney, NSW 2006

with contributions from: M. Ballantine, S. Boulton, L. Buza, D. Cunningham, L. Halasz, M.Humphreys, I. Ermayanti, C. Keller, F. Knight, N. Lam, R. Last, N. Leist, J. Matarczyk, B. Mitchell, B. Mumbulla, S. Smith, G. Toohey, V. Torrisi, T. Wardill, P. Wilkey.

Introduction

Yaouk Peak (35°51'S 148°52'E) is c. 65 km SSW from Canberra and lies south of the A.C.T. border in N.S.W. The peak rises to 1725 m above sea level from a broad rocky ridge top. This ridge top is treeless and shrub dominated from about 1700 m up to the peak. The substrate is composed of porphyritic leucogranite, with muscovite leucogranite to the west of the peak (Snelling 1960). Humic skeletal soil occurs on the ridge top, but is often quite shallow. Deeper loams occur at the woodland margins.

A field trip to Yaouk Peak was undertaken by students participating in the Australian National Herbarium's (CANB) Botanical Internship Programme. The twenty interns assisted by Herbarium staff visited the Peak on the 9th January 1996 to make collections. The range of habitats on the treeless ridge-top was sampled haphazardly in order to find as much floristic diversity as possible. As such, the species list in Table 1 must be considered a preliminary one. Most of the collections were made on the treeless ridge-top above 1700 m, although some collections were from the lower, woodland margins.

Heath vegetation, predominantly *Leptospermum namadgiensis* Lyne, *L. micromyrtus* Miq. and *Kunzea muelleri* Benth. partially covers the ridge top area, between many exposed rocky surfaces. The surrounding woodland is dominated by *Eucalyptus pauciflora* Sieber ex Sprengel with *E. debeuzevillei* Maiden also present. *Eucalyptus pauciflora* and *Hakea lissosperma* R.Br. are occasionally emergent on the higher areas. The flora of this peak was previously poorly known, as only a few collections had been made there (Table 1).

Leptospermum namadgiensis and *Olearia rhizomatica* Lander ms were found on Yaouk Peak. These collections increase the known geographic ranges of both species (Fig. 1). As very few collections have been made of both of these species, the distributions may still be incomplete.

The collections made on the trip have been determined, databased and incorporated into the CANB collection. The flora known to date of Yaouk Peak is listed in Table 1, and predominantly reflects the flora of the treeless ridge top.

Table 1: Species present on Yaouk Peak

Known flora of Yaouk Peak. New records in bold type. Existing records from ANHSIR and IBIS.

F - frequent **O** - occasional **U** - uncommon **R** - rare
*Observed but not collected

Species	Local Frequency
Cryptogams:	
Cladonia sp	O
Filicopsida:	
Aspleniaceae	
Asplenium flabellifolium Cav.	R
Dryopteridaceae	
Polystichum proliferum (R. Br.) Presl	R
Magnoliopsida–Magnoliideae:	
Asteraceae	
Celmisia sp. nov. _a_	O
_C._ sp. nov. b	F
Lagenifera stipitata subsp. _stipitata_ (Labill.) Druce	O
Olearia rhizomatica Lander ms	O
Ozothamnus thyrsoideus DC.	R
Campanulaceae	
Pratia puberula Benth.	O
Caryophyllaceae	
Stellaria pungens Brongn.	F
Clusiaceae	
Hypericum japonicum Thunb.	O
Euphorbiaceae	
Poranthera microphylla Brongn.	O
Geraniaceae	
Geranium antrorsum Carolin	R
Goodeniaceae	
Goodenia hederaceae subsp. _alpestris_ (K. Krause) Carolin	F
Fabaceae	
Acacia alpina F. Muell.	F
Oxylobium alpestre F. Muell.	F
Oxylobium ellipticum (Labill.) R. Br.*	O
Lamiaceae	
Westringia lucida B. Boivin	O
Myrtaceae	
Eucalyptus debeuzevillei Maiden*	U
E. pauciflora Sieber ex Spreng	F
Kunzea ericoides (A. Rich.) J. Thompson	R
K. muelleri Benth.	F
Leptospermum micromyrtus Miq.	F
L. namadgiensis Lyne	F
Proteaceae	
Grevillea lanigera Cunn. ex R. Br.	O
Hakea lissosperma R. Br.	O
Rutaceae	
Phebalium squamulosum subsp. *ozothamnoides* (F. Muell.) Paul G. Wilson	R
Scrophulariaceae	
Derwentia perfoliata (R. Br.) B. Briggs & Ehrend.	F
Thymeliaceae	
Pimelea linifolia subsp. _linifolia_ Smith	O
Violaceae	
Viola betonicifolia subsp. _betonicifolia_ Sm.	O
Magnoliopsida - Liliideae:	
Anthericaceae	
Arthropodium milleflorum (DC.) J.F. Macbr.	O
Juncaceae	
Luzula flaccida (Buchenau) Edgar	O
Orchidaceae	
Chiloglottis valida D.L. Jones	U
Poaceae	
Poa labillardieri var. _labillardieri_ Steud.	F
Deyeuxia monticola var. _monticola_ (Roem. & Shult.) Vickery	R

Discussion

Yaouk Peak vegetation can be described as a mixture of predominantly subalpine (*sensu* Thompson 1981) and rocky heath species (*sensu* Helman & Gilmour 1985).

BIOCLIM generates climate estimates based on meteorological data and topographical information (Busby 1991). User input of the distribution of taxa is used to create climatic profiles, which can subsequently allow predictions of further distributions of these taxa (Busby 1991). BIOCLIM requires precipitation and temperature information, but does not take substrate into account. *Leptospermum namadgiensis* has only been found on a limited number of substrates, namely porphyritic and muscovitic leucogranite (Yaouk Peak), undifferentiated leucogranite (Scabby Range) and granodiorite (The Sentry Box and Mt Namadgi). As *L. namadgiensis* has not been found on nearby peaks of similar climate and altitude (Mt Morgan—as predicted by

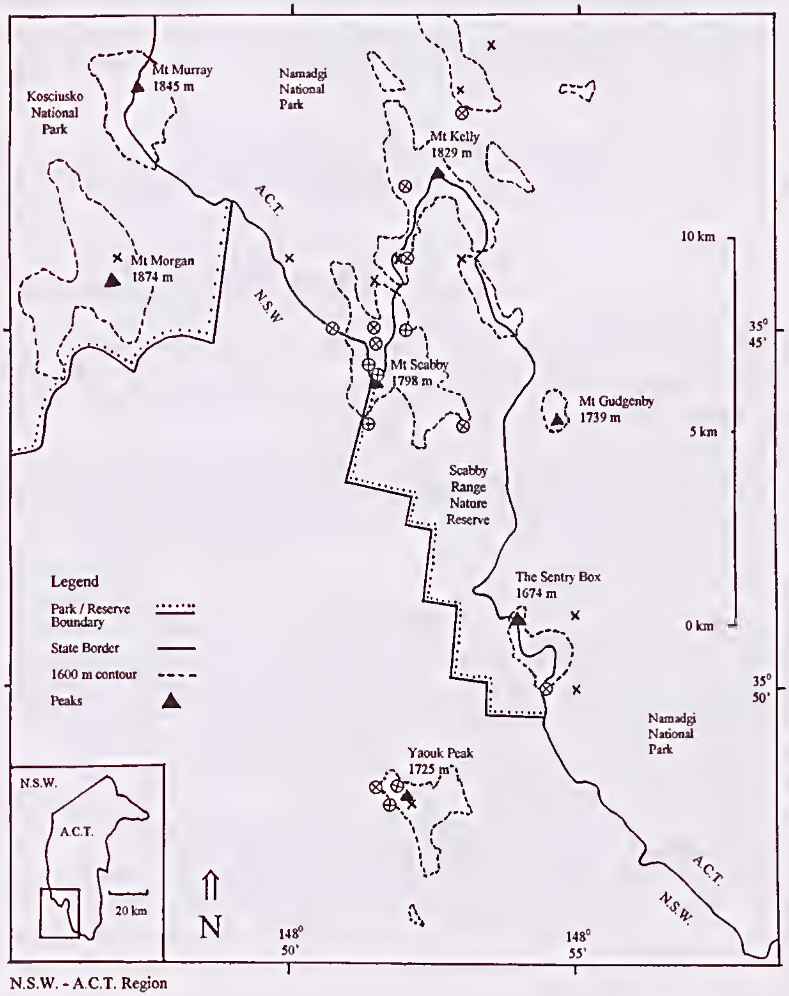

Fig. 1. Distribution of *Leptospermum namadgiensis* Lyne ⊗ and *Olearia rhizomatica* Lander ms ×

BIOCLIM), it appears that *L. namadgiensis* may be restricted to certain substrates. Further experimentation would be needed to properly test this hypothesis.

Olearia rhizomatica is found on the same substrates as *Leptospermum namadgiensis* but in addition it is found on Mt Morgan (adamellite and granodiorite). *Olearia rhizomatica* appears not to be as restricted by substrate as *L. namadgiensis*.

Conservation implications

Leptospermum namadgiensis is known from populations within Namadgi National Park and Scabby Range Nature Reserve. Lyne (1993) considered that a conservation code of 2RCat was appropriate for this taxon according to the criteria outlined by Briggs & Leigh (1996). As Yaouk Peak does not lie within a conservation reserve, this code should be amended to 2RCa.

Olearia rhizomatica has been recorded from Namadgi and Kosciusko National Parks, and Scabby Range Nature Reserve. *Olearia rhizomatica* is listed by Briggs & Leigh (1996) and has been given a conservation code of 2RCit. Again, this should be amended to 2RCi. The citation of *O. rhizomatica* in the Tinderry Nature Reserve (Briggs & Leigh 1996) is incorrect, as the specimen from there is not conspecific (I.R. Telford pers. comm.)

The populations of *Leptospermum namadgiensis* and *Olearia rhizomatica* on Yaouk Peak do not appear to be threatened, as the area is unsuitable for agricultural purposes.

Acknowledgments

I would like to thank the following organisations and people: the Centre for Plant Biodiversity Research (CPBR) for the opportunities provided by the Botanical Internship Programme; H. Hewson, I. Telford, A. Lyne and J. Palmer for their help, time and patience; P. Hohnen and S. York for their help with database queries; CBG for the use of their library; the administration staff at the Herbarium for use of their computer; and M. Henwood (SYD) for his assistance with the final drafts.

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CUNNINGHAMIA

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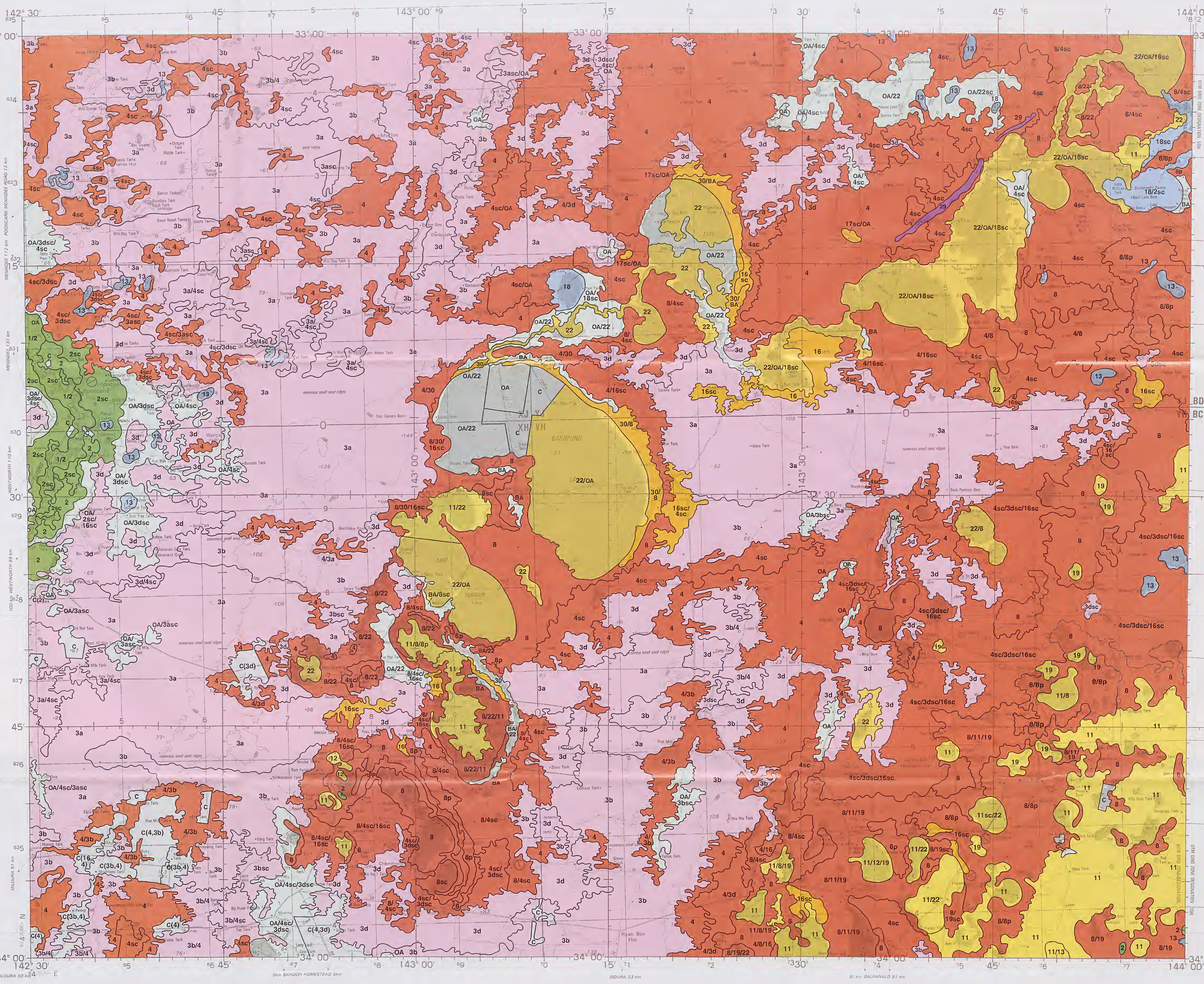

Natural Vegetation

of the

POONCARIE
(New South Wales)

1:250 000 Map Sheet

Marianne F. Porteners
Elizabeth M. Ashby
John S. Benson

Descriptions of the plant communities are given in *Cunninghamia* 5(1) 1997

Compiled and prepared at the
National Herbarium of New South Wales

ROYAL BOTANIC GARDENS SYDNEY

Understanding the ecology of our native plants

MAP UNIT DESCRIPTIONS

No.	Plant Community	Main Species	Structure	Habitat
1	**Riverine Forest**	*Eucalyptus camaldulensis*	open forest	Areas subject to frequent or periodic flooding - river and creek levees, adjacent flats and associated billabongs and swamps on grey and brown clays.
2	**Black Box Woodland**	*Eucalyptus largiflorens*	woodland - open woodland	Uppermost floodplain levels, in depressions, along minor creeks, on adjacent flats, dry-lake margins, on grey and brown clays.
16	***Callitris* Woodland**	*Callitris glaucophylla*	woodland - isolated clumps	Raised low linear dunes, sandhills and ridges on red and brown earths and loams.
17	***Acacia melvillei* Woodland**	*Acacia melvillei*	isolated trees - open woodland	Level to undulating sandplains on red-brown sandy loam.
30	**Lunette Shrubland**	*Dodonaea viscosa* subsp. *angustissima*	shrubland - sparse shrubland	Lake lunettes, lunette remnants and disturbed sandy areas, on white calcareous sands to light red-brown sandy loam.
4	**Belah-Rosewood**	*Casuarina pauper* *Alectryon oleifolius* subsp. *canescens*	open woodland - isolated clumps	Level to undulating sandplains on red to red-brown calcareous earths, reddish-brown sands and duplex soils.
8	**Black Bluebush**	*Maireana pyramidata*	chenopod shrubland - sparse chenopod shrubland	Level to undulating sandplains, scalded plains, low sandy rises and lunette remnants on red-brown sands, loams and duplex soils.
8p	**Pearl and Black Bluebushes**	*Maireana sedifolia*, *Maireana pyramidata*	chenopod shrubland - sparse chenopod shrubland	Associated with 8 where the red-brown loamy soils are more calcareous.
3a	**Irregular Dune Mallee**	*Eucalyptus socialis*, *Triodia scariosa* subsp. *scariosa*	mallee shrubland - open mallee shrubland	Dunefields with irregular or discontinuous linear or subparabolic dunes on deep, sandy red soils.
3b	**Linear Dune Mallee**	*Eucalyptus socialis*, *Eucalyptus dumosa*, *Triodia scariosa* subsp. *scariosa*	mallee shrubland - open mallee shrubland	Dunefields with continuous, east-west aligned linear dunes on deep loamy sand to sandy red soils.
3d	**Sandplain Mallee**	*Eucalyptus socialis*, *Sclerolaena obliquicuspis*, *Dissocarpus paradoxus*, *Stipa nitida*	mallee shrubland - open mallee shrubland	Level to undulating sandplains, often with low, discontinuous, linear dunes on sandy loams derived from aeolian materials.
29	**Rocky Outcrop Woodland Complex**	*Callitris glaucophylla*, *Eucalyptus intertexta*	open woodland - isolated trees	Low rocky outcrops of quartzite, sandstone, siltstone and shale with brown gravelly sandy loam or skeletal soils.
11	**Bladder Saltbush**	*Atriplex vesicaria*	chenopod shrubland - open chenopod shrubland	Dry lake beds, isolated shallow depressions and level to depressed alluvial plains on deep, grey cracking clays to red clay-loams.
12	***Sclerostegia tenuis***	*Sclerostegia tenuis*, *Disphyma crassifolium* subsp. *clavellatum*	closed - open chenopod shrubland	Saline flats and depressions on clay soils.
19	**Old Man Saltbush**	*Atriplex nummularia*	chenopod shrubland - open chenopod shrubland	Level to depressed plains, low-lying areas with grey-brown loams and cracking clays.
22	**Disturbed Shrubland Complex**	*Dissocarpus paradoxus*, *Nitraria billardierei*	shrubland - sparse shrubland	Disturbed low-lying alluvial plains, floodplains and dry lakebeds on grey to grey-brown clay and loam soils, often saline.
13	**Canegrass**	*Eragrostis australasica*	tussock grassland	Depressions and other low-lying areas subject to intermittent flooding or ponding with slightly saline, compact, heavy grey clays.
18	**Lignum and Nitre Goosefoot**	*Muehlenbeckia florulenta*, *Chenopodium nitrariaceum*	open - closed shrubland	Depressions, channels, river-flats and swamps where flooding is relatively infrequent, but often prolonged. Soils are heavy grey to grey-brown cracking clays.
OA	**Open Areas**	various grasses, herbs and forbs	grassland - forbland	Highly disturbed areas usually dominated by weeds.
BA	**Bare Areas**	Areas naturally bare of any vegetation, often including lake lunettes and shifting dunes.		
C	**Cleared and/or cropped**	Native vegetation has largely been removed for agricultural or urban development but remnant vegetation of varying sizes and condition may remain. Where possible, pre-cleared vegetation and remnant types are indicated in brackets following C.		
sc.	**scattered**	Plants are scattered.		

Present vegetation as at March 1995. Clearing marked from LANDSAT TM imagery dated 12-10-1991 to 10-03-1992, and from colour aerial photographs dated 28-06-1993.

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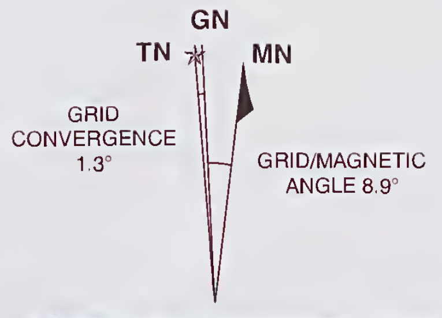

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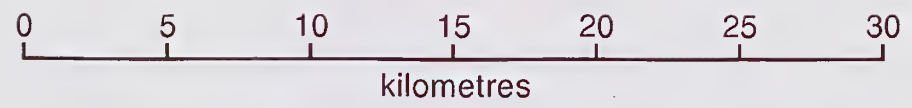

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Vegetation community 1 Riverine Forest

Structure: open forest.

Main species: *Eucalyptus camaldulensis* (River Red Gum).

Commonly associated native species: *Acacia stenophylla, Muehlenbeckia florulenta, Chenopodium nitrariaceum, Enchylaena tomentosa, Sclerolaena muricata* var. *muricata, Einadia nutans* subsp. *nutans, Atriplex leptocarpa, Panicum effusum, Eucalyptus largiflorens, Marsilea drummondii, Oxalis perennans, Paspalidium jubiflorum.*

Landform: River and creek levees, adjacent flats and associated billabongs and swamps; all subject to frequent or periodic flooding.

Soils: Self-mulching to silty grey clays; heavy grey and brown clays.

Distribution: This community occurs along the Darling River in the far central-west of the map. Smaller creeks tend to be fringed with Black Box Woodland, although *Eucalyptus camaldulensis* will occur where there has been periodic flooding.

Vegetation community 2 Black Box Woodland

Structure: woodland - open woodland.

Main species: *Eucalyptus largiflorens* (Black Box).

Commonly associated native species: *Enchylaena tomentosa, Einadia nutans* subsp. nutans, *Atriplex semibaccata, Dissocarpus paradoxus, Salsola kali, Osteocarpum acropterum* var. *deminuta, Rhagodia spinescens, Sclerolaena muricata* var. *muricata, Atriplex* eardleyae, *Sclerolaena brachyptera, Solanum esuriale, Chenopodium cristatum, Maireana brevifolia, Muehlenbeckia florulenta, Chamaesyce drummondii, Chenopodium nitrariaceum, Oxalis perennans.*

Landform: Uppermost floodplain levels, ephemeral creeks and adjacent flats, dry-lake margins, depressions, drains and channels.

Soils: Silty or cracking, grey and brown clays.

Distribution: Black Box Woodland is infrequent across the map, occurring in depressions, along minor creeks and fringing dry lakes. The greatest densities occur adjacent to *Eucalyptus camaldulensis* open forest on the upper levels of the Darling River floodplain. Black Box occurs in relatively dense stands in Gunnaramby Swamp in the far north-east, and along the channels of Willandra Creek.

Vegetation community 3a, 3b & 3d: Mallee

Structure: mallee shrubland to open mallee shrubland (rarely open mallee woodland).

There are three types of Mallee communities identified on the map - Irregular Dune Mallee (3a), Linear Dune Mallee (3b) and Sandplain Mallee (3d).

3a: Irregular Dune Mallee

Main species: *Eucalyptus socialis* (Pointed Mallee), *Triodia scariosa* subsp. *scariosa* (Porcupine Grass).

Commonly associated native species: *Sclerolaena diacantha, Eucalyptus dumosa, Acacia wilhelmiana, Sclerolaena parviflora, Stipa nitida, Dodonaea viscosa* subsp. *angustissima, Podolepis capillaris, Eucalyptus leptophylla, Eucalyptus costata, Eucalyptus gracilis, Eucalyptus oleosa, Halgania cyanea, Lomandra leucocephala* subsp. *robusta, Maireana triptera, Chenopodium desertorum* subsp. *desertorum, Calotis erinacea, Sclerolaena obliquicuspis, Acacia rigens, Bossiaea walkeri, Duboisia hopwoodii, Leptospermum coriaceum, Ptilotus exaltatus* var. *exaltatus.*

Landform: Dunefields with irregular or discontinuous linear, parabolic or subparabolic dunes.

Soils: Deep, sandy red soils; leached, non-calcareous siliceous sands.

Distribution: Irregular Dune Mallee is the most common mallee type of the map and occurs throughout the area; large continuous tracts occur in the central-east and west.

3b: Linear Dune Mallee

Main species: *Eucalyptus socialis* (Pointed Mallee), *Eucalyptus dumosa* (Congoo Mallee), *Triodia scariosa* subsp. *scariosa* (Porcupine Grass), *Sclerolaena diacantha* (Grey Copperburr).

Commonly associated native species: *Dodonaea viscosa* subsp. *angustissima, Stipa nitida, Eucalyptus gracilis, Acacia colletioides, Enchylaena tomentosa, Eremophila glabra, Sclerolaena parviflora, Maireana triptera, Chenopodium desertorum* subsp. *desertorum, Eucalyptus costata, Eucalyptus leptophylla, Eucalyptus oleosa, Halgania cyanea, Ptilotus exaltatus* var. *exaltatus, Salsola kali, Sclerolaena obliquicuspis, Zygophyllum apiculatum, Acacia wilhelmiana, Atriplex stipitata, Maireana pentatropis, Maireana sclerolaenoides, Vittadinia cuneata* var. *cuneata, Bossiaea walkeri, Chenopodium curvispicatum, Senna artemisioides* subsp. *petiolaris.*

Landform: Dunefields with continuous, east-west aligned linear dunes.

Soils: Deep loamy sand to sandy red soil; calcareous sands; calcareous loamy red earths in swales.

Distribution: Linear Dune Mallee occurs throughout the map, particularly in the central-south and far south-west.

3d: Sandplain Mallee

Main species: *Eucalyptus socialis* (Pointed Mallee), *Sclerolaena obliquicuspis* (Limestone Copperburr), *Dissocarpus paradoxus* (Cannonball Burr), *Stipa nitida* (Speargrass).

Commonly associated native species: *Eucalyptus dumosa, Eucalyptus gracilis, Enchylaena tomentosa, Maireana triptera, Sclerolaena diacantha, Atriplex stipitata, Chenopodium desertorum* subsp. *desertorum, Salsola kali, Zygophyllum apiculatum, Maireana pentatropis, Maireana sclerolaenoides, Marsdenia australis, Sclerolaena patenticuspis, Eucalyptus oleosa.*

Landform: Level to undulating sandplains, often with low, discontinuous, linear dunes.

Soils: Calcareous loamy sand to sandy red and brown loams; earths with sandy loam surface and red desert loams derived from aeolian materials.

Distribution: Sandplain mallee occurs throughout the map, most commonly in the eastern half, but also adjacent to the Darling River floodplain in the west. The community tends to occur on deeper sandplains adjacent to areas of Belah-Rosewood.

Vegetation community 4: Belah-Rosewood

Structure: open woodland - isolated clumps.

Main species: *Casuarina pauper* (Belah), *Alectryon oleifolius* subsp. *canescens* (Rosewood).

Commonly associated native species: *Enchylaena tomentosa, Sclerolaena obliquicuspis, Dissocarpus paradoxus, Stipa nitida, Sclerolaena diacantha, Atriplex stipitata, Maireana triptera, Senna artemisioides* nothosubsp. *coriacea, Geijera parviflora, Myoporum platycarpum* subsp. *platycarpum, Eremophila sturtii, Callitris glaucophylla, Maireana pyramidata, Sclerolaena patenticuspis, Apophyllum anomalum, Dodonaea viscosa* subsp. *angustissima, Exocarpos aphyllus, Rhagodia spinescens, Flindersia maculosa.*

Landform: Level to undulating sandplains, often with isolated sandy rises.

Soils: Calcareous earths, mainly of red to red-brown loam to loamy sand; solonised brown soils to sandy red earths; reddish-brown sands and texture-contrast (duplex) soils.

Distribution: Belah-Rosewood is common throughout the Pooncarie map area. The most dense and continuous stands occur in the north to north-east.

Vegetation community 8 & 8p: Bluebush

Structure: chenopod shrubland - sparse chenopod shrubland.

There are two closely-associated communities of Bluebush - Black Bluebush (8) and Pearl Bluebush (8p), the distribution of which is dependent on the limestone content of the soil.

8: Black Bluebush

Main species: *Maireana pyramidata* (Black Bluebush).

Commonly associated native species: *Dissocarpus paradoxus, Stipa nitida, Sclerolaena brachyptera, Atriplex lindleyi, Nitraria billardierei, Rhagodia spinescens, Sclerolaena obliquicuspis, Sclerolaena patenticuspis, Maireana sedifolia.*

Landform: Level to undulating sandplains, scalded plains, low sandy rises, lunette remnants.

Soils: Red-brown loams and duplex soils with sandy topsoils and clayey subsoils; calcareous sands and loams; particularly where limestone lies at a depth of 1.2 m or more below the surface (Beadle 1948).

Distribution: This shrubland community is common throughout the mapped area, particularly in the east at the transition from the aeolian landscape to the alluvial Hay Plain. It also occurs on lunettes and raised, scalded, duplex soil areas adjacent to dry lakes.

8p: Pearl Bluebush

Main species: *Maireana sedifolia* (Pearl Bluebush), *Maireana pyramidata* (Black Bluebush).

Commonly associated native species: *Dissocarpus paradoxus, Sclerolaena brachyptera, Stipa nitida, Enneapogon avenaceus, Rhagodia ulicina.*

Landform: Level to undulating sandplains, scalded plains, low sandy rises, lunette remnants.

Soils: Calcareous red-brown loamy soils; particularly where where limestone nodules lie within 60 cm of the surface (Beadle 1948).

Distribution: This shrubland community is uncommon throughout the mapped area, and occurs patchily in the east to south-east, and on lunette remnants of the Willandra Lakes.

Vegetation community 11: Bladder Saltbush

Structure: chenopod shrubland - open chenopod shrubland.

Main species: *Atriplex vesicaria* (Bladder Saltbush).

Commonly associated native species: *Sclerolaena brachyptera, Disphyma crassifolium* subsp. *clavellatum, Sclerolaena tricuspis, Sclerostegia tenuis, Osteocarpum acropterum* var. *deminuta, Dissocarpus paradoxus, Dissocarpus biflorus* var. *biflorus, Malacocera tricornis, Minuria cunninghamii, Nitraria billardierei, Atriplex lindleyi, Sclerolaena divaricata, Sclerolaena intricata, Sclerolaena muricata* var. *muricata.*

Landform: Dry lake beds and level to depressed alluvial plains.

Soils: Deep, grey, self-mulching and cracking clays to red clay-loam; grey clays and clay-loams to sandy loams overlying clay.

Distribution: *Atriplex vesicaria* shrubland occurs on the alluvial plains in the far south-east of the map, and in isolated shallow depressions and dry lake beds throughout. Relatively dense stands occur in Lake Mungo within Mungo National Park.

Vegetation community 12: *Sclerostegia tenuis*

Structure: closed - open chenopod shrubland.

Main species: *Sclerostegia tenuis* (Slender Glasswort), *Disphyma crassifolium* subsp. *clavellatum* (Round-leaf Pigface).

Commonly associated native species: *Atriplex vesicaria, Eragrostis australasica, Atriplex lindleyi, Sclerolaena divaricata, Sclerolaena tricuspis, Sclerolaena muricata* var. *muricata, Osteocarpum acropterum* var. *deminuta, Sclerolaena brachyptera.*

Landform: Saline flats and depressions, depressed alluvial plains.

Soils: Clay soils in saline situations.

Distribution: Occurs in scattered localities within depressed saline flats in the south-east of the map and in the Willandra Lakes region.

Vegetation community 13: Canegrass

Structure: tussock grassland.

Main species: *Eragrostis australasica* (Canegrass).

Commonly associated native species: *Sclerolaena tricuspis, Maireana microcarpa, Muehlenbeckia florulenta, Sclerolaena muricata* var. *muricata, Sclerostegia tenuis.*

Landform: Swamps, table drains, claypans, alluvial plains with depressions and other low-lying areas subject to intermittent flooding or ponding.

Soils: Slightly saline, compact, heavy grey clays.

Distribution: Canegrass occurs in saline depressions at scattered localities throughout the mapped area.

Vegetation community 16: *Callitris* Woodland

Structure: woodland - isolated clumps.

Main species: *Callitris glaucophylla* (White Cypress Pine).

Commonly associated native species: *Enchylaena tomentosa, Salsola kali, Chenopodium cristatum, Alectryon oleifolius* subsp. *canescens, Dissocarpus paradoxus, Erodium crinitum, Nicotiana velutina, Casuarina pauper, Maireana brevifolia, Maireana pyramidata, Sclerolaena diacantha, Sclerolaena obliquicuspis, Solanum esuriale.*

Landform: Raised sandy areas such as low linear dunes, sandhills and ridges.

Soils: Sandy soils; coarse-textured red and brown earths; red-brown sandy-loams.

Distribution: Isolated sandhills with *Callitris* Woodland occur throughout the map, particularly within Belah-Rosewood sandplain areas. The largest area of *Callitris glaucophylla* occurs south-east of Mulurulu Lake on a long, continuous sandy ridge extending several kilometres.

Vegetation community 17: *Acacia melvillei* Woodland

Structure: isolated trees - open woodland.

Main species: *Acacia melvillei* (Yarran).

Commonly associated native species: *Dissocarpus paradoxa, Enchylaena tomentosa, Sclerolaena obliquicuspis, Eremophila sturtii, Stipa nitida, Acacia homalophylla, Sclerolaena diacantha.*

Landform: Level to undulating sandplains.

Soils: Red-brown sandy loam soil; reddish loam flats.

Distribution: Only a few small remnant areas of *Acacia melvillei* occur on the map. *Acacia melvillei* can occur as groves or small local communities within *Callitris* Woodland and Belah-Rosewood.

Vegetation community 18: Lignum and Nitre Goosefoot

Structure: open - closed shrubland.

Main species: *Muehlenbeckia florulenta* (Lignum), *Chenopodium nitrariaceum* (Nitre Goosefoot).

Commonly associated native species: *Salsola kali, Sclerolaena muricata* var. *muricata, Teucrium racemosum, Marsilea drummondii, Eragrostis australasica.*

Landform: Intermittently flooded depressions, channels, river-flats and swamps. Flooding is relatively infrequent, but often prolonged.

Soils: Heavy grey to grey-brown cracking clays.

Distribution: This community occurs infrequently throughout the map in swamps adjacent to the Darling River and Willandra Creek systems and in scattered low-lying depressions.

Vegetation community 19: Old Man Saltbush

Structure: chenopod shrubland - open chenopod shrubland.

Main species: *Atriplex nummularia* (Old Man Saltbush).

Commonly associated native species: *Maireana pyramidata, Atriplex lindleyi, Osteocarpum acropterum* var. *deminuta, Chenopodium nitrariaceum, Einadia nutans* subsp. *nutans, Rhagodia spinescens, Salsola kali, Sclerolaena divaricata, Sclerostegia tenuis, Atriplex vesicaria, Sclerolaena tricuspis.*

Landform: Level to depressed plains, low-lying areas and depressions.

Soils: Grey-brown loams to grey and brown cracking clays.

Distribution: This community occurs in scattered localities in the east to south-east of the map.

Vegetation community 22: Disturbed Shrubland Complex

Structure: shrubland or chenopod shrubland - sparse shrubland or sparse chenopod shrubland.

Main species: *Dissocarpus paradoxus* (Cannonball Burr), *Nitraria billardierei* (Dillon Bush).

Commonly associated native species: *Maireana aphylla, Sclerolaena tricuspis, Salsola kali, Atriplex lindleyi, Euphorbia planiticola, Atriplex holocarpa, Chamaesyce* species B, *Panicum decompositum, Danthonia caespitosa, Osteocarpum acropterum* var. *deminuta, Sclerolaena brachyptera,* occasionally remnant *Atriplex vesicaria, Neobassia proceriflora, Sclerolaena divaricata, Sclerolaena intricata, Sclerolaena muricata.* This community occupies disturbed areas and usually comprises a high proportion of introduced and annual species. Other common native species vary depending on the composition of the original vegetation.

Landform: Disturbed low-lying alluvial plains, floodplains and dry lakebeds.

Soils: Grey to grey-brown clay and loam soils, often saline.

Distribution: This disturbed shrubland predominates on the previously cropped and/or heavily grazed lake beds of the Willandra Lakes system, and also occurs in scattered depressions and dry lakes throughout the map.

Vegetation community 29: Rocky Outcrop Woodland Complex

Structure: open woodland to isolated trees.

Main species: *Callitris glaucophylla* (White Cypress Pine), *Eucalyptus intertexta* (Western Red Box).

Commonly associated native species: *Enchylaena tomentosa, Einadia nutans* subsp. *nutans, Sida intricata, Sclerolaena convexula, Solanum ferocissimum, Chamaesyce drummondii, Erodium crinitum, Goodenia fascicularis, Phyllanthus fuernrohrii, Vittadinia gracilis, Acacia aneura, Acacia burkittii, Eriostemon linearis.* Ferns such as *Cheilanthes distans, Cheilanthes lasiophylla, Cheilanthes sieberi* subsp. *sieberi* and *Pleurosorus rutifolius* grow under rocky overhangs and in moist crevices.

Landform: Footslopes, ridges and crests of low rocky outcrops. Outcropping of quartzite and sandstone, pebbly to conglomeratic in part, siltstone and shale.

Soils: Brown to dark brown shallow sandy loam with surface stones and gravel, sandstone lithosols or skeletal soils; becoming redder and better developed downslope.

Distribution: Manfred Range, in the far north-east, is the only sizeable rocky outcrop on the map.

Vegetation community 30: Lunette Shrubland

Structure: shrubland - sparse shrubland.

Main species: *Dodonaea viscosa* subsp. *angustissima* (Narrow-leaf Hopbush).

Commonly associated native species: *Salsola kali, Stipa nitida, Myriocephalus stuartii, Maireana pyramidata, Acacia ligulata, Pittosporum phylliraeoides.*

Landform: Lake lunettes, lunette remnants and disturbed areas, usually highly eroded.

Soils: White calcareous sands to light red-brown sandy loam.

Distribution: This community occurs on the crescent-shaped lunettes and patchier lunette remnants on the eastern edges of the large dry lakes in the Willandra Lakes system. The lunettes of Garnpung and Mulurulu Lakes carry dense areas of Hopbush. Hopbush also occurs as localised stands, particularly in cleared areas, within Belah-Rosewood, Mallee and other sandplain communities.

Open Areas (OA)

These are highly disturbed areas with a vegetation cover of annual or short-lived perennial grasses, herbs, forbs and few shrubs. Open Areas result from intense grazing, erosion, clearing and fire. Introduced pasture species usually predominate, such as **Hordeum leporinum, *Lamarckia aurea, *Bromus rubens, *Avena fatua* and **Medicago* spp. Native grasses may include *Stipa nitida, Enneapogon avenaceus, Danthonia caespitosa, Dactyloctenium radulans* and *Sporobolus caroli.* The composition of annual herbs changes seasonally but may include **Asphodelus fistulosus, *Salvia verbenaca, Erodium* spp., *Ptilotus* spp., *Swainsona* spp., asteraceous herbs and annual saltbushes. Open Areas may also carry outbreaks of Narrow-leaf Hopbush (*Dodonaea viscosa* subsp. *angustissima*) and Turpentine (*Eremophila sturtii*). Weeds often dominate the more disturbed Open Areas such as road verges, table drains and heavily used paddocks.

Bare Areas (BA)

These areas are naturally bare of any vegetation and include lake lunettes and other isolated and often shifting dunes. The deep, white, calcareous sands of lunette remnants are highly susceptible to erosion. Bare areas are not uncommon in the Willandra Lakes area.

Cleared Areas (C)

These areas have been almost entirely cleared of natural vegetation and are often cultivated for agricultural purposes.

Cunninghamia

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